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NAVAL ARCHITECTURE.

No. 2.

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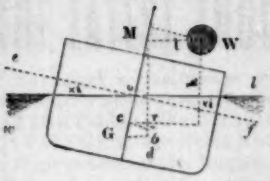
STABILITY.

Statical Stability is the moment of force which a body in flotation exerts to attain its normal position or that of equilibrium, it having been deflected from it, and it is equal to product of weight of fluid displaced and horizontal distances between the two centres of gravity of body and of displacement, or it is product of weight of displacement, height of *meta-centre* and sine of angle of inclination.

Dynamical Stability is amount of mechanical work necessary to deflect a body in flotation from its normal position or that of equilibrium, and it is is equal to product of sum of vertical distances through which centre of gravity of body descends and centre of buoyancy descends, in moving from vertical to inclined position by weight of body.

TO DETERMINE MEASURE OF STABILITY OF HULL OF A VESSEL OR OF A FLOATING BODY.

The measure of stability of a floating body depends essentially upon



horizontal distance, G *b*, of *meta-centre* of body from centre of gravity of the body; and it is product of the force of the water, or resistance to displacement of it, acting upward, and the distance of G *b*, or P×G *b*. If distance, *c* M, ir represented by *r*, and the angle of rolling, *c* M *r*, by M°, the measure of stability or S is determined by P *r*, sin. M°=S; and this is therefore greater, the greater the weight of the body, the greater the distance of *meta-centre* from centre of gravity of the body, and the greater the angle of inclination of this or of *c* M *r*.

Assume figure to represent transverse section of hull of a vessel, G centre of gravity of hull, *w l* water-line, and *c* centre of buoyancy or of displacement of immersed hull in position of equilibrium. Conceive the vessel to be heeled or inclined over, so that *e f* becomes the water-line, and *b* centre of buoyancy of the immersed section; produce *b* M, and the point M is *meta-centre** of the hull of the vessel.

Comparattve Stability of different hulls or vessels is proportionate to the distance of G M for same angles of heeling, or of distance G *b*. Oscillations of hull of a vessel may be resolved into a rolling about its longitudinal axis, pitching about its transverse axis and vertical pitching, consisting in rising and sinking below and above position of equilibrium.

If transverse section of hull of a vessel is such that, when vessel heels, the level of centre of gravity is not altered, then its rolling will be about a permanent longitudinal axis traversing its centre of gravity, and it will not be accompanied by any vertical oscillations or pitchings, and the moment of its *inertia* will be constant while it rolls. But if, when hull heels, the level of its centre of gravity is altered, then axis about which it rolls becomes an instantaneous one, and the moment of

* The transverse *meta-centre* depends upon position of centre of buoyancy, for it is that point, where a vertical line drawn from the centre, intersects a line passing through the centre of gravity of the hull of the vessel perpendicular to plane of the keel.

The point of *meta-centre* may be the same, or it may differ slightly for different angles of heeling. The angle of direction adopted to ascertain the position of the *meta-centre* should be the greatest which, under ordinary circumstances, is of probable occurrence; in different vessels this angle ranges from 20° to 60°.

If *meta-centre* is above the centre of gravity, the equilibrium is Stable; if it coincides with it, the equilibrium is Indifferent; and if it is below it, the equilibrium is Unstable.

its *inertia* will vary as it rolls; and rolling, must then necessarily be accompanied by vertical oscillations.

Such oscillations tend to strain a vessel and her spars, and it is desirable, therefore, that transverse section of hull should be such that centre of its gravity should not alter as it rolls, a condition which is always secured if all water-lines, as *w l* and *e f*, are tangents to a common sphere described about G; or, in other words, if the point of their intersections, *o*, with the vertical plane of keel, is always equidistant from the centre of gravity of the hull.

TO COMPUTE STATICAL STABILITY.

$D \times c\ M$ sin. $M = S$, *D representing displacement, M angle of inclination, and S stability.*

ILLUSTRATION 1. Assume a ship weighing 6000 tons is heeled to an angle of 9°, distance $c\ M = 3$ feet,

Sin. $9° = \cdot1564$,

Then $6000 \times 3 \times \cdot1564 = 2815\cdot2$ *foot-tons.*

ILLUSTRATION 2. Weight of a floating body is 5515 pounds, distance between its centre of gravity and *meta-centre* is 11·32 feet, and angle $M = 20°$.

Sin. $M = \cdot34202$.

Hence $5515 \times 11\cdot32 \times \cdot34202 = 21352\cdot24$ *foot-pounds.*

TO COMPUTE ELEMENTS OF STABILITY OF A FLOATING BODY.

$$\frac{A'}{A}\, a = s,\ \frac{c}{\text{sin. } M} = r,\ \frac{s}{\text{sin. } M} = g \text{ and sin. } M\ r = c.$$

A representing area of immersed section; A′ section immersed by careening of body, as f o l; s horizontal distance c r, between centres of buoyancy; a horizontal distance between centres of gravity i i, of areas immersed and emerged by careening; g distance c M, between centre of buoyancy or of water displaced and meta-centre; r distance G M, between centre of gravity and meta-centre; c horizontal distance G b, between the centre of gravity and of line of displacement of it when careened, e vertical distance between centre of gravity and buoyancy, all in feet; and M angle of careening.

NOTE.—When centre of gravity G, is below that of displacement, *c*, then *e* is +; when it is above *c* it is —; and when it coincides with *c* it is 0; or *e* is — when $\frac{S}{P} < s$; and a body will roll over when *e* sin. $M =$ or $> s$.

The assumed elements of figure illustrated are $A = 86$, $A' = 21{\cdot}5$, $b = 21{\cdot}5$ and $e = {\cdot}5$.

The deduced are $s = 3{\cdot}7$, $c = 3{\cdot}87$, $g = 10{\cdot}82$, $a = 14{\cdot}9$ and $r = 11{\cdot}32$, *b representing breadth at water-line or beam in feet and P weight or displacement in pounds or tons.*

The $s = \frac{21{\cdot}5}{86} \times 14{\cdot}8 = 3{\cdot}7$ feet, $r = \frac{3{\cdot}87}{{\cdot}34202} = 11{\cdot}32$ feet, $e = r - g$, $g = \frac{3{\cdot}7}{{\cdot}34202} = 10{\cdot}82$ feet, $c = {\cdot}34202 \times 11{\cdot}32 = 3{\cdot}87$ feet.

Of Hull of a Vessel.—$\left(\frac{b^3}{10{\cdot}7 \text{ to } 13^* A} \pm e\right) P$, sin. $M = S$; d cos. ${\cdot}5\ M = d'$, $\frac{b^3}{10{\cdot}7 \text{ to } 13\,(11{\cdot}93)\,A} = g$, $\frac{1}{\text{sin. } M}\left(\frac{S}{P} - s\right) = \pm e$; $P\left(\frac{ba}{A} + e \text{ sin. } M\right) = S$; and $P\,(s \pm e \text{ sin. } M) = S$.

d representing depth of centre of gravity of displacement under water in equilibrium, and d' the depth when out of equilibrium, all in feet.

Illustration.—Displacement of a vessel is 10,000,000 pounds; breadth of beam, 50 feet; area of immersed section, 800 square feet; vertical distance from centre of gravity of hull up to centre of buoyancy or displacement, 1·9 feet, and horizontal distance *a* between centres of gravity of areas immersed and emerged, when careened to an angle of $9^\circ\ 10'' = 33{\cdot}4$ feet, the immersed area being 50 square feet.

sin. $9^\circ\ 10'' = {\cdot}1593$

Then $s = \frac{50}{800} \times 33{\cdot}4 = 2{\cdot}0875$ feet, $800 \times 2{\cdot}0875 = 50 \times 33{\cdot}4$, $r = \frac{2{\cdot}39}{{\cdot}1593} = 15$ feet.

$g = \frac{50^3}{11{\cdot}93 \times 800} = 13{\cdot}1$ feet, $S = \left(\frac{50^3}{11{\cdot}93 \times 800}\right) + 1{\cdot}9 \times 10{,}000{,}000 \times {\cdot}1593 = 23{,}905{,}396$ pounds, and $e = \frac{1}{{\cdot}1593}\left(\frac{23905396}{10000000} - 2{\cdot}0875\right) = 1{\cdot}9$ feet.

Illustration 2.—Assume a ship having a displacement of 5000

* Unit for the section of a parallelogram is 16·7; of a semicircle, 12, and of a triangle, 12·8.

tons and a height of *meta-centre* of 325 feet, to be careened to 6° 12′ —what is her statical stability?

Sin. 6° 12′ = ·1079

Then 5000 × 3·25 × ·1079 = 1753·37 foot tons.

ILLULTRATION 3.—Assume a weight, *W*, of 50 tons to be placed upon her spar deck, having a common centre of gravity of 15 feet above her load-line.

Then $5000 \times 3{\cdot}25 - \overline{50+15} \times {\cdot}1079 = 1745{\cdot}29$ foot tons.

ILLUSTRATION 4.—Assume 100 tons of water ballast to be admitted to her tanks at a common centre of gravity of 15 feet below her load-line.

Then $5000 \times 3.25 + \overline{100 \times 15} \times {\cdot}1079 = 1915{\cdot}22$ foot tons.

ILLUSTRATION 5.—Assumeme her masts, weighing 6 tons, to be cut down 20 feet.

Then $\frac{10 \times 20}{5000} = \frac{2}{50}$ foot = fall of centre of gravity and $5000 \times \left(3{\cdot}25 = \frac{2}{50}\right) \times {\cdot}1079 = 1774{\cdot}95$ tons.

TO COMPUTE ELEMENTS OF POWER, ETC., REQUIRED TO CAREEN A BODY OR VESSEL.

$$\text{Sin. } M\,(h - \overline{n \text{ sin. } M}) + \overline{n \text{ sec. } M} - s = l$$

$$\frac{b^3}{10{\cdot}7 \text{ to } 13\ A\ l^2} \sqrt{\frac{P}{64{\cdot}125\ L\ A}} = m$$

$$W\,l\,r = P\,c \text{ and } W\,l = S.$$

W representing weight or power exerted and l distance at which weight or power acts to careen body taken from centre of gravity of displacement perpendicular to careening force, h vertical height from centre of gravity of displacement to centre of weight or power to careen body when it is in equilibrium, n horizontal distance from centre of vessel to centre of weight or power, L length of vessel and m meta-centre and S as in preceding case, all in feet.

ILLUSTRATION.—A weight is placed upon deck of a vessel at a mean distance of 3·87 feet from centre line of hull; height at which it is placed is 11·32, and other elements as in first case given.

Sec. 20° = ·342

Then $h = 11{\cdot}32$, $n = 3{\cdot}87$ and $l = {\cdot}342\ (1{\cdot}3 - \overline{3{\cdot}87 \times {\cdot}342}) + \overline{3{\cdot}87 \times 1{\cdot}0642} - 3{\cdot}7 = {\cdot}342 \times 10 + 4{\cdot}12 - 3{\cdot}7 = 3{\cdot}84$ feet.

Assume $W = 5515$.

Then $5515 \times 3{\cdot}84 = 21187{\cdot}6$ foot pounds.

Or $P\ (w \cos.\ M + h \sin.\ M) = S$, *w representing distance of weight from centre of vessel and h height of w above water-line, both in feet.*

ILLUSTRATION.—If a weight of 30 tons placed at 20 feet from centre of hull or deck, 10 feet above water-line, careens it to an angle of 2° 9′, what is its stability?

cos. 2° 9′ = ·9993 — sin. 2° 9′ = ·0375

$30\ (20 \times {\cdot}9993 + 10 \times {\cdot}0375) = 30 \times 20{\cdot}361 = 610{\cdot}83$ foot tons.

STATICAL SURFACE STABILITY.

Moment of statical surface stability at any angle is $c\ z \times D$. Assuming centre of gravity of vessel coincided with *c*, coefficient of a vessel's stability at any angle of heel is expressed when the displacement is multiplied by vertical height of the *meta-centre* for the given angle of heel above centre of gravity or $D \times c\ M$.

Approximately. RULE.—Divide moment of inertia of plane of flotation for the upright position, relatively to the middle line by volume of displacement; and quotient multiplied by sine of angle of heel will give result.

Per Foot of Length of Vessel, $\frac{2}{3}\ (B^3 \times \sin.\ M)$, *B representing half breadth.*

DYNAMICAL SURFACE STABILITY.

Moment of dynamical surface stability is expressed by product of weight of vessel or displacement and depression of centre of buoyancy during the inclination, that is for angle *M*.

TO COMPUTE DYNAMICAL STABILITY OF A VESSEL.

Approximately. RULE.—Multiply displacement by height of *meta-centre* above centre of gravity and product by versed sine of angle of heel.

Or multiply statical stability for given angle by tangent of one-half angle of heel.

TABLE AND DIAGRAM FOR DETERMINING THE DIAMETERS OF SPEED CONES WHEN CONNECTED BY AN OPEN BELT OF CONSTANT LENGTH.

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The difficulty in the way of a short and accurate solution of this problem is the complex and transcendental nature of the equation which expresses the relation between the diameters of any belted pair of steps.

The equation itself is easily enough obtained from Fig. 1 as follows:

$$l = R\left(\frac{\pi}{2}+B\right)+r\left(\frac{\pi}{2}-B\right)+s\cos.B\frac{\pi}{2} \qquad (1)$$

$$R-r=s\sin B \qquad (2)$$

where l represents the half length of the belt.

In order that the belt may have equal tension on every pair of steps, it must be of constant length, consequently

$$l = R_1\left(\frac{\pi}{2}+B_1\right)+r_1\left(\frac{\pi}{2}-B_1\right)+s\cos.B_1 = R\left(\frac{\pi}{2}+B\right)$$
$$+r\left(\frac{\pi}{2}-B\right)+s\cos.B \qquad (3)$$

or $$(R_1+r_1)\frac{\pi}{2}+(R_1-r_1)B_1+s\cos.B_1 = R(R+r)$$
$$+(R-r)B+s\cos.B \qquad (4)$$

which last equation expresses the relation between the radii R_1 and r_1 of any pair of steps.

The data for determining the unknown diameters in the two cases occurring in practice are as follows:

Case I. Given all the diameters D, D_1, D_2 and D_3 on one cone A, one diameter d on cone B and the distance s between the axes.

Case II. Given the diameter D and d of one belted pair of steps, the ratios $\frac{D_1}{d_1}$, $\frac{D_2}{d_2}$ and $\frac{D_3}{d_3}$ of the diameters of the other pairs and the distance s between the axes.

If we now follow the usual method and reduce equations 2 and 4

to a single equation containing but one unknown quantity, by means of the data given either in Case I or Case II, we will get for both these cases

$$\text{sin. } B + a\ B \text{ sin. } B + b \text{ cos. } B = c \qquad (5)$$

a, b and c being functions of known quantities. By developing sin. B and cos. B according to the ascending powers of the arc B,

$$\text{sin. } B = B - \frac{B^3}{1.2.3} + \frac{B^5}{1.2.3.4.5} - \text{etc.}$$

$$\text{cos. } B = 1 - \frac{B^2}{1.2} + \frac{B^4}{1.2.3.4} - \text{etc.}$$

and substituting in equation 5 we will get an equation that will contain powers of the arc B only, and which may be solved by any one of the well known trial methods. As soon as B is found its sine may be substituted in equation 2, and the required diameter obtained. But calculations by trial methods are tedious processes, even when all powers higher than the third are neglected, consequently graphical methods, based on the above series, have been devised for determining the required diameters, but these are only applicable within quite narrow limits, and even then are only approximately true.

That no table has hitherto been calculated for determining the diameters of speed cones is probably due to an idea that the above laborious or inaccurate methods were the only possible ones; but this is not the case, as the following explanation of how the writer obtained the present table will show:

Combining equations 1 and 2 we get

$$l = (R + r)\frac{\pi}{2} + s\ B \text{ sin. } B + s \text{ cos. } B \qquad (6)$$

which is easily transformed into

$$\frac{l}{s} = \frac{\pi}{4}\frac{D+d}{s} + B \text{ sin. } B + \text{cos. } B \qquad (7)$$

and this again into

$$\frac{D+d}{s} = \frac{2}{\pi}\frac{L}{s} - \frac{4}{\pi}(B \text{ sin. } B + \text{cos. } B) \qquad (8)$$

where $\frac{D+d}{s}$ may be regarded as the sum of the diameters of any belted pair, and $\frac{L}{s}$ the whole length of belt when the distance between the axes is unity.

It is evident that there can be calculated from equation 8 a table of values of $\frac{D+d}{s}$ corresponding to assumed values of $\frac{2}{\pi}\frac{L}{s}$ and $\frac{4}{\pi}(B \sin. B + \cos. B)$ as arguments, provided these latter are kept within the limits of the problem. Now an inspection of Fig. 1 will show that these limits are as follows:

For the angle B	0°	and 90°
" $\sin. B$	0	and 1·
For $\frac{4}{\pi}(B \sin. B + \cos. B)$	1·273	and 2·
and corresponingly for $\frac{L}{s}$	2	and 6·283
" $\frac{2}{\pi}\frac{L}{s}$	1·273	and 4·

Within these limits we have considerable range in our choice of values for the arguments, and may therefore choose them so that the tabular differences for adjacent values of $\frac{2}{\pi}\frac{L}{s}$ shall equal some constant number, as ·100 or ·200, for this will not only facilitate interpolation, but will greatly reduce the number of terms to be calculated from the formula. In calculating the accompanying table, therefore, the successive values of $\frac{2}{\pi}\frac{L}{s}$ differ by 0·200, and those of $\frac{4}{\pi}(B \sin. B + \cos. B)$ in such a manner that $\frac{D-d}{s} = 2\frac{R-r}{s} = 2 \sin. B$ was successively equal to 0, 0·1, 0·2, etc. The next step was to substitute in the table for $\frac{D+d}{s}$ the separate values $\frac{D}{s}$ and $\frac{d}{s}$, these being determined from the well known relations:

$$D = \frac{D+d}{S} + \frac{D-d}{S} \qquad d = \frac{D+d}{S} - \frac{D-d}{S}$$

and then write $\frac{L}{s}$ for $\frac{2}{\pi}\frac{L}{s}$ and $\frac{D-d}{s}$ for $\frac{4}{\pi} B \sin. B + \cos. B$. The table was then completed.

Now although the length of belt enters into the computation of the table and has been placed in the latter as an argument, it need not be known to solve either Case I or Case II. The object of placing it in the table was simply to indicate the series of belted pairs having the

same length of belt. It should also be remembered that the preceding formulas take no account of thickness of belt, consequently both the given and required diameters must be reqarded as extending to the centre of the belt.

We can best show how this table is to be used by the following examples:

Example 1.—Given the four diameters, 4″, 8″, 14″, 20″ on cone *A*,
one diameter, — — 14″, — on cone *B*,
and the distance between the axes equal to 40″.

Required the remaining diameters of the steps on cone *B*.

The given pair consisting of equal steps, we have $\frac{D-d}{s} = \frac{14-14}{40}$ $= 0$, and must therefore look along the first horizontal series of pairs for the diameter $\frac{14}{40} = \cdot 350$, in order that we may find the column corresponding to the length of belt connecting these particular cones. The quantity ·350 evidently lies half way between columns 3 and 4, and corresponds to a length of belt $\frac{L}{s} = \frac{2\cdot 944 + 3\cdot 258}{2} = 3\cdot 101$. As the differences between the adjacent values of columns 3 and 4 are everywhere ·100, we can get, if desired, another column corresponding to the length of belt, 3·101, by simply adding ·050 to all the values in column 3, thus getting the series of pairs

·350	·399	·447	·493	·537	·580
·350	·299	·247	·193	·137	·080

the upper and lower rows corresponding respectively to the larger and smaller diameters of the pairs. To get the other member of the belted pair to which the 4″ step belongs we must look for $\frac{4}{40} = 1\cdot 100$ along the lower row of this series and will find that the next lower term is ·080, and then interpolating we obtain for the ratio of the required diameter to distance of the axes

$$\cdot 580 - (\cdot 100 - \cdot 080)\,\frac{43}{57} = \cdot 565$$

Multiplying this ratio ·565 by 40″ gives 22·6 for the required diameter. Proceeding in the same manner for the next step, we have, since $\frac{8}{40} = .200$,

Table containing the EFFECTIVE *Diameters of the Companion Steps of Speed Cones, for Constant Lengths of Open Belt, and for Axes a Unit's Distance Apart.*

Diff. of Diams. of steps $D-d$	$\frac{L}{s}=$ 2·316	2·630	2·944	3·258	3·572	3·886	4·200	4·514	4·828	5·142	5·456	Differences.	Contact of Belt on smaller Step.
s	1	2	3	4	5	6	7	8	9	10	11		α.
0·0	·100 ·100	·200 ·200	·300 ·300	·400 ·400	·500 ·500	·600 ·600	·700 ·700	·800 ·800	·900 ·900				180°
												49 51	
0·1	·149 ·049	·249 ·149	·349 ·249	·449 ·349	·549 ·449	·649 ·549	·749 ·649	·849 ·748	·949 ·849	1·049 ·949			174°
												48 52	
0·2		·297 ·097	·397 ·197	·497 ·297	·597 ·397	·697 ·497	·797 ·597	·897 ·697	·997 ·797	1·097 ·897			169°
												46 54	
0·3		·343 ·043	·443 .143	·543 ·243	·643 ·343	·743 ·443	·843 ·543	·943 ·643	1·043 ·743	1·143 ·843			163°
												44 56	
0·4			·487 ·087	·587 ·187	·687 ·287	·787 ·387	·887 ·487	·987 ·587	1·087 ·687	1·187 ·787			157°
												43 57	
0·5			·530 ·030	·630 ·130	·730 ·230	·830 ·330	·930 ·430	1·030 ·530	1·130 ·630	1·230 ·730			151°
												41 59	
0·6				·671 ·071	·771 ·171	·871 ·271	·971 ·371	1·071 ·471	1·171 ·571	1·271 ·671			145°
												40 60	
0·7				·711 ·011	·811 ·111	·911 ·211	1·011 ·311	1·111 ·411	1·211 ·511	1·311 ·611			139°
												37 63	
0·8					·848 ·048	·948 ·148	1·048 ·248	1·148 ·348	1·248 ·448	1·348 ·548			133°
												36 64	
0·9						·984 ·084	1·084 ·184	1·184 ·284	1·284 ·384	1·384 ·484			127°
												35 65	
1·0						1·019 ·019	1·119 ·119	1·219 ·219	1·319 ·319	1·419 ·419			120°
												32 68	
1·1							1·151 ·051	1·251 ·151	1·351 ·251	1·451 ·351			113°
												31 69	
1·2								1·282 ·082	1·382 ·182	1·482 ·282	1·582 ·382		106°
												28 72	
1·3								1·310 ·010	1·410 ·110	1·510 ·210	1·610 ·310		99°
												26 74	
1·4									1·436 ·036	1·526 ·136	1·636 ·236		91°
												25 75	
1·5										1·561 ·061	1·661 ·161		83°
												21 79	
1·6											1·682 ·082		74°
												20 80	
1·7											1·702 ·002		64°

$$\cdot 493 - (\cdot 200 - \cdot 193)\frac{46}{54} = \cdot 487$$

for the required ratio. $\cdot 487 \times 40 = 19 \cdot 48$, the required partner of the 8″ step.

Interpolating in like manner for the 20″ step, $\frac{24}{40} = 0 \cdot 5$ being looked for however in the upper row of our series, we get

$$\cdot 193 - (\cdot 500 - \cdot 493)\frac{56}{44} = \cdot 184,$$

which, multiplied by 40, gives 7·36 for the companion of the 20″ step.

The belted pairs of our two cones are therefore as follows:

4	8	14	20	on cone *A*,
$22\frac{5}{8}$	$19\frac{1}{2}$	14	$7\frac{3}{8}$	" " *B*.

The next example gives a shorter method of obtaining the required diameters, and differs from the preceding problem in having the steps of the given belted pair of unequal, instead of equal, diameters.

Example 2.—Given the diameters 6, 12, 18, 24 on cone *B*,
diameter 32, — — — " " *A*,
and the distance between the axes = 50″.

Required as before the unknown diameters of *B*.

Here $\frac{D-d}{s} = \frac{32-6}{50} = \cdot 520$ means that we must look between the 6th and 7th horizontal series of pairs for $\frac{6}{50} = \cdot 120$, in order that we may find the column corresponding to the length of belt on these cones. Interpolating between the lower rows we find

$$\cdot 120 - \left[\cdot 130 - (\cdot 52 - \cdot 50)\frac{59}{100}\right] = \cdot 002$$

as the quantity which must be added to column 4 in order to obtain the tabular series corresponding to the length of belt in the present case; this series obtained we could proceed as in first example. But we can also obtain the required results without finding this series, namely, as follows: Look for $\frac{12}{50} - \cdot 002 = \cdot 238$ in column 4 and find the corresponding difference $\frac{D-d}{s}$ of the diameters of this belted pair in the column at the left of the table by the following interpolation:

$$\frac{D_1-d_1}{s}=0{\cdot}3+(\dot{2}43-{\cdot}238)\frac{100}{59}={\cdot}309$$

Multiplying this difference by 50 and adding the product to 12 we get, for the partner of the latter, $27\frac{7}{16}''$. In like manner the fellow of the 18″ step may be obtained by finding the difference $\frac{D_2-d_2}{s}$ corresponding to $\frac{18}{50}-{\cdot}002={\cdot}358$ of column 4.

$$\frac{D_2-d_2}{s}=0{\cdot}0+({\cdot}400-{\cdot}358)\frac{100}{51}={\cdot}082$$

then multiplying this difference by 50 and adding the product to 18, the sum $22\frac{1}{8}''$ is the diameter of the required step. For the partner of 24″ step we must look for $\frac{24}{50}-{\cdot}002={\cdot}478$ among the larger members of the pairs in column 4. Its corresponding difference will be

$$\frac{D_3-d_3}{s}=0{\cdot}1+({\cdot}478-{\cdot}449)\frac{100}{48}={\cdot}160$$

The product of this difference by 50 *subtracted* from 24″ gives 16 as the diameter of the required step.

The belted pairs of the speed cones will then be as follows:

6	12	18	24
32	$27\frac{7}{16}$	$22\frac{1}{8}$	16

From the last column of the table can be obtained, if desired, the arc of contact of belt on the smaller step; for the above pairs they are as follows:

$$\alpha=150^\circ \quad 162^\circ \quad 175^\circ \quad 17\iota^\circ$$

and from the top of the table we get for the length of belt

$$50\left(3{\cdot}258+\frac{{\cdot}002}{{\cdot}100}\times{\cdot}314\right)=163''$$

Example 3.—Given the number of revolutions of speed cone $A=240$, and the distance between the axes $=40''$.

Required that the steps be so chosen that the cone B may make 100, 240, 400 and 580 revolutions per minute.

If we assume that 30 feet per second would be a suitable maximum velocity of belt on these speed cones, and that D is the diameter of the step on cone A, which transmits 580 revolutions to the step d on cone B, we will get from

$$\frac{D}{12}\times 3{\cdot}14\times\frac{240}{60}=30$$

$$D = 29'' \text{ nearly and } d = \frac{240}{580} \times 29'' = 12''$$

We can now make use of the table, first finding, as in the previous examples, the column corresponding to the length of belt connecting D with d. Since $\frac{D-d}{s} = \frac{29-12}{40} = \cdot 425$, we must look between the 5th and 6th horizontal series of pairs for $\frac{12}{40} = \cdot 300$, and will then find that it lies in a series obtained by adding

$$\cdot 300 - \left[\cdot 287 - (\cdot 425 - \cdot 400)\,\frac{57}{100}\right] = \cdot 027$$

to the values of column 5. Along the series of pairs thus obtained we must now look for the particular pair

$$\cdot 597 + \cdot 027 = \cdot 624$$
$$\cdot 397 + \cdot 027 = \cdot 424$$

whose diameters bear to each other a ratio most nearly equal to $\frac{D_1}{d_1} = \frac{400}{240} = \frac{5}{3}$. If to the numerator of this next lower ratio $\frac{\cdot 624}{\cdot 424}$ we add the proper fraction of the tabular difference between the larger diameters and subtract from the denominator the same fraction of the tabular difference between the smaller diameters, the resultant ratio will equal the required one, or if x represents the aforesaid proper fraction we must have

$$\frac{D_1}{d_1} = \frac{\cdot 624 + x \times \cdot 046}{\cdot 424 - x \times \cdot 054} = \frac{5}{3}$$

We have now only to solve this equation of the first degree with respect to x and then substitute x in the fraction constituting its first member, in order to find that in the numerator we have the larger and in the denominator the smaller member of the required pair. x is here equal to 0·61, consequently $\frac{D_1}{d_1} = \frac{\cdot 652}{\cdot 391}$ and $D_1 = \cdot 652 \times 40 = 26 \cdot 08$ and $d_1 = \cdot 381 \times 40 = 1564$.

In like manner we can first find x and then D_3 and d_3 from

$$\frac{d_3}{D_3} = \frac{240}{100} = \frac{\cdot 687 + \cdot 027 + x \times \cdot 043}{\cdot 287 + \cdot 027 - x \times \cdot 057}$$

x being here equal to 0·22.

$$\frac{d_3}{D_3} = \frac{\cdot 723}{\cdot 301} \qquad d_3 = \cdot 723 \times 40 = 28 \cdot 92 \text{ and } D_3 = \cdot 301 \times 40 = 12 \cdot 04$$

Since $\frac{D_2}{d_2} = \frac{240}{240} = 1$, we easily find $D_2 = d_2 = (500 + \cdot 027) \times 40 = 21 \cdot 08$.

The required pairs are, therefore, as follows:

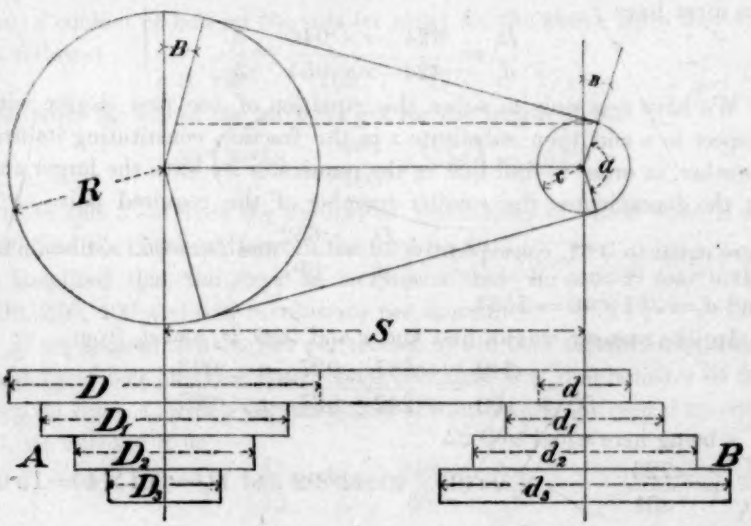
12·04	21·08	26·08	29	on cone *A*
28·92	21·08	15·64	12	" *B*

The blank spaces of the table represent impossible cases. It should, also, be noticed that for differences $\frac{D-d}{s} < \cdot 2$, the sum of the diameters, is nearly constant; consequently, if the greatest difference between the companion steps of a pair of cones does not exceed $0 \cdot 2\ s$, we may calculate the diameter of these cones as if they were connected by a crossed belt, that is, as if the sum of the diameters was constant.

Besides the foregoing table, the writer has also calculated another, in which the ratio of one of the diameters of a belted pair to the distance between the axes is assumed, and its partner colculated for different lengths of belt, the assumed diameters forming an arithmetical series, whose first term is ·05 and whose difference is also ·05. This last table, though apparently simpler than the one here given, is not so convenient for interpolation.

For those who do not interpolate readily we have added the diagram explained below.

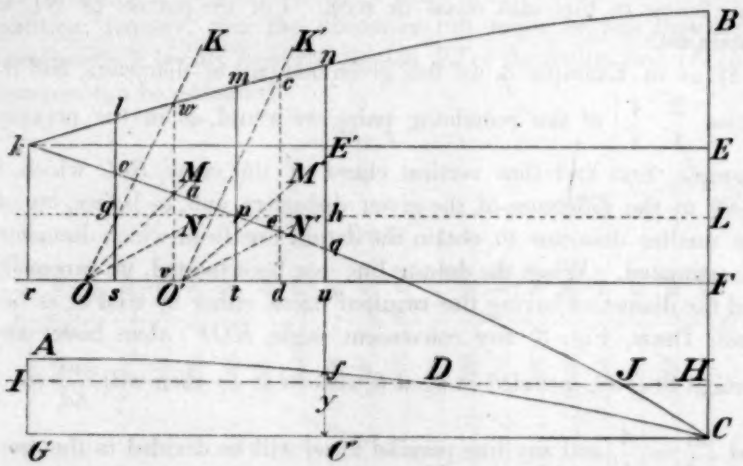
Fig. 1.



Of all the graphical methods which have been devised for solving the speed cone problem, that of Prof. Culmann is the only one which is exact; it is, moreover, the only one which possesses the time-saving property of needing to be constructed but once in order to be applicable to every speed cone problem which may arise in practice. The only objection to be made to Culmann's diagram is, that though easy of application, and not difficult to understand, it nevertheless requires considerable time and care for its accurate construction. The writer has sought to remove this objection to the diagram by calculating the ordinates of the curve forming its essential feature.

Reversing the usual methods of presenting these subjects, we will first show how this curve is to be used in solving speed cone problems, then how the ordinates may be calculated, and finally will explain Cullmann's method of constructing the curve.

Fig. 2.



In Fig. 2 each one of the vertical chords, as *ol*, represents the difference between the diameters of some belted pair of steps, the greatest possible vertical chord, *BC*, being equal to $2s$, or twice the distance between the axes. Both the given and required diameters are estimated from some horizontal line, as *rF*, which we call the datum line. The different positions of the datum line correspond to different lengths of belt.

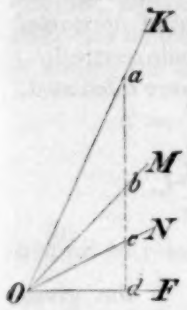
Now suppose we had given all the diameters of cone *A*, one diameter of cone *B*, and the distance $2s$ between the axes.

If we now take *BC*, Fig. 2, as the linear representative of $2s$, and to the same scale $\frac{MT}{PT}$ *OS*, *RR* and *NU* as the linear equivalents of the given diameters, we can find the required partners of *OS*, *RR* and *NU* by the following process. We first find (by trial) that vertical chord *mp* of the curve *BkC*, which is equal to the difference *MT—PT* of the diameters of the given pair; from the lower end of the chord thus found we then lay off *pt*, equal to the smaller diameter *PT* of the given pair, and through *t* draw the horizontal or datum line *rtF*. To find the companion of *OS* we have simply to find the point *o* on the curve *BkC*, whose distance *os* from the datum line *rtF* is equal to *OS*; then, drawing a vertical line through *o*, we will have in *ls* the required diameter to the scale $\frac{BC}{2s}$. Form the companion step to *KR* we obtain its equal, *kr*, the difference between the members of the belted pair being in this case equal to zero. For the partner of *NU* we obtain *nu*.

If, as in Example 3, we had given one pair of diameters, and the ratios $\frac{2}{1}$, $\frac{4}{1}$, of the remaining pairs, we would, as in the previous example, first find that vertical chord of the curve *BkC* which is equal to the difference of the given diameters, and, as before, lay off the smaller diameter to obtain the datum line from which diameters are estimated. When the datum line has been located, we can easily find the diameters having the required ratios, either by trial or as follows: Draw, Fig. 3, any convenient angle, *KOF*; then bisect any vertical line, *ad*, included in it, at *b*, also *bd* at *c*; then will $\frac{ad}{bd} = \frac{2}{1}$ and $\frac{ad}{cd} = \frac{4}{1}$, and any line parallel to *ad* will be divided in the same proportion by the rays *OF*, *ON*, *OM* and *OK*. Now, if Fig. 3 had been drawn on some such transparent material as tracing cloth, the line *OF* might be placed upon and moved along the datum line *rF*, Fig. 2, till the respective intersections of the rays *OK* and *OM*, with the upper and lower branches of the curve *BkC*, were in the same vertical line, as at *wa*, Fig. 2; then would *wv* and *av* be the diameters having the required ratio $\frac{wv}{av} = \frac{2}{1}$. Moving *OF* of Fig. 3 still fur-

ther along the datum line rF of Fig. 2, we would obtain in like manner the diameters cd and ed with the required ratio $\frac{cd}{ed} = \frac{4}{1}$.

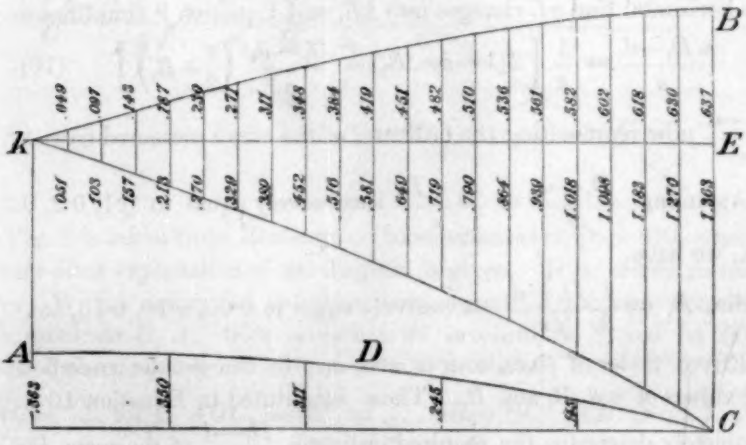
Fig. 3.



As the sum of the radii of the steps cannot be greater than the distance between the axes, there is evidently a limit to the size of the steps for every given difference of diameters; these limits taken together form another curve, CDA, Fig. 2. The vertical lines qf and nf included between this curve and the two branches of BkC are the maximum diameters for the given difference nq, for $qf = nf = BC = 2s$.

It follows from this, that only from that portion of the datum line DH which falls above the limiting curve CDA can diameters be estimated. But even the portion DH cannot be wholly thus used, for there is still another very evident condition, namely, that the diameters can never be less than zero, consequently it is only from the portion DJ of the datum line IH that diameters can be estimated.

Fig 4.



We have given in Fig. 4 the ordinates of the upper and lower branches of the curve BkC shown in Fig. 2. The ordinates were chosen so that the chords or differences of diameter should form an

arithmetical series whose first term was 0 and difference 0·1. These ordinates were made equidistant on Fig. 4 as a matter of convenience, only, for the diagram gives correct results even when the increments of the abscissas are not constant, the reason of this being that, since both data and results are vertical quantities, any amount of *horizontal* distortion is permissible which allows the chords to remain vertical.

We will now explain how the ordinates of Fig. 4 were calculated. Equation 4 was first transformed into

$$\frac{D_1-d}{s}=\frac{1}{\pi}\left(\frac{D-d}{s}\left(\frac{\pi}{2}+B\right)+2\cos.B-\left[\frac{D_1-d_1}{s}\left(\frac{\pi}{2}+B_1\right)+2\cos.B_1\right)\right] \qquad (9)$$

when $\frac{D-d}{s}$ is the given difference mp, Fig. 2, and $\frac{d}{e}$ the given smaller diameter pt, determining the datum line rF, and as $\frac{D_1-d_1}{s}$ is any other difference of diameters lo, $\frac{D_1-d}{s}$ must represent such lines og or lg, or the distance of the curve BkC from the line gL, drawn through the foot of the vertical chord mp. By taking $\frac{D-d}{s}=o$, the horizontal line gL changes into kE, and Equation 9 simplifies to

$$\frac{D_1-d}{s}=\frac{1}{\pi}\left[2(1-\cos.B_1)-\frac{D_1-d_1}{s}\left(\frac{\pi}{2}+B_1\right)\right] \qquad (10)$$

$\frac{D_1-d}{s}$ now representing the ordinates of the curve measured from kE.

Assuming $\frac{D_1-d_1}{s}$ or $\frac{d_1-D_1}{s}$ successively equal to 0·1, 0·2, 0·3, etc., we have

Sin. $B_1=\frac{1}{2}\frac{D_1-d_1}{s}$ successively equal to 0·05, 0·10, 0·15, etc.

and from tables of sines, cosines and arcs we can get the corresponding values of cos. B_1 and B_1. These substituted in Equation 10 will completely determine the required ordinates $\frac{D_1-d}{s}$ of the curve BkC.

The ordinates of the curve ADC, Figs. 2 and 4, are are now also easily obtained from

$$y = E^1 C^1 - (E^1 q + q f) = 1{\cdot}363 - \left[\frac{D_1 - d}{s} + \left(1 - \frac{D_1 - d_1}{2s}\right)\right] \quad (11)$$

We have thus far only stated the essential features of Culmann's diagram, without attempting to prove them, and will now seek to make this omission good by showing that the diagram can be obtained by finding the linear equivalents of the following equations,

$$R = \frac{l}{\pi} - \frac{s}{\pi}(B \sin. B + \cos. B) + \frac{s}{2} \sin. B \quad (12)$$

$$r = \frac{l}{\pi} - \frac{s}{\pi}(B \sin. B + \cos. B) - \frac{s}{2} \sin B. \quad (13)$$

obtained by combining Equations 1 and 2.

Fig. 5.

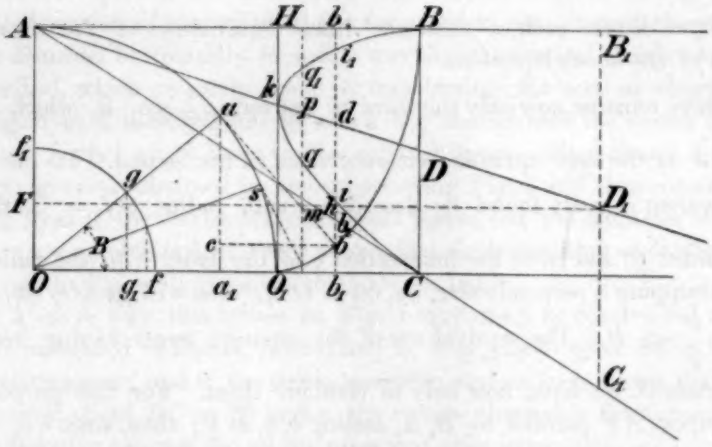


Fig. 5 is taken from Reuleaux's *Constructionslehre*, page 610, where a very clear explanation of the diagram is given. It is, briefly, as follows: With a radius $OA = s$ (the distance apart of the axes) describe the quadrant $O_1 A$; then construct its involute, $O_1 B$, and let fall from B the perpendicular BC on to OO_1 produced; then will $AB = OC_1 = \frac{s\pi}{2}$ for $< AOO_1 = 90° = \frac{\pi}{2}$. Since $BC : AB :: s : \frac{s\pi}{2}$ we have

$$BC = \frac{2}{\pi} AB$$

Bisecting BC at D, we have $BD = \frac{AB}{\pi}$ and $B_1 D_1 = D_1 C_1 = \frac{A_1 B_1}{\pi}$

Now, if we choose $AB_1 = l$, we shall have for the linear equivalent of the first term $\frac{l}{\pi} = B_1 D_1 = D_1 C_1$.

Now let a radius, Oa, make with OO_1 any angle, B, less than 90°, and drop the perpendicular aa_1 from a; then will $Oa_1 = Oa \cos. B = s \cos. B$. Now draw a tangent to the quadrant at a; it will cut the involute at b, and its length $ab = aO_1 = sB$. Since $< a_1 ab = B$, we have

$$bc = a_1 b_1 = ab \sin. B = sB \sin. B,$$

and therefore $b_1 O = (b_1 a_1 + a_1 O) = s (B \sin. B + \cos. B)$.

Prolonging $b_1 b$ till it intersects AB at b_0 we have again, as above,

$$db_0 = db_2 = \frac{Ab_0}{\pi} = \frac{b_1 O}{\pi} = \frac{s}{\pi} (B \sin. B + \cos. B$$

or $db_0 = db_2$ are each of them the linear equivalents of the second term of the above equations.

There remains now only the third or last term, $\frac{s}{2}$ sin. B, which is added in the first equation, but subtracted in the second. Its linear equivalent is easily found by describing with radius $Of = \frac{s}{2}$ the quadrant ff, and from the intersection g of the latter with the radius Oa dropping a perpendicular, gg, on to OO_1; then will $gg = Og$ sin. $B = \frac{s}{2}$ sin. B. The equivalents of the separate terms having been ascertained, we have now only to combine them. For this purpose we draw AF parallel to $B_1 A$, cutting $b_0 b_1$ at h; then, since $h b_0 = D_1 B_1 = \frac{b}{\pi}$ we will have

$$dh - hb_0 - db_0 = \frac{l}{\pi} - \frac{s}{\pi} (B \sin. B + \cos. B)$$

for the combination of the first and second terms.

Now, making $di = di_1 = gg = \frac{s}{2}$ sin. B, we will have

$$R = hi_1 = dh + di_1 = \frac{l}{\pi} - \frac{s}{\pi} (B \sin. B + \cos. B) + \frac{s}{2} \sin. B$$

$$r = hi = dh - di = \frac{l}{\pi} - \frac{s}{\pi} (B \sin. B + \cos. B) - \frac{s}{2} \sin. B$$

for a particular value of the angle B. Other angles of B will give different values for the radii R and r; for example, if we retain the same length, l, the same angle, $O_1 Os = B_1$, will give for the larger diameter $R_1 = mq$, and for the smaller diameter $r_1 = mq$. Connecting the points i, i_1, q, q, etc., we obtain a curve, BkC, which needs to be constructed but once, for it will not vary with l, because $di = di_1 = \frac{s}{2}$ sin. B are independent of l.

Since the radii R, r, R_1 and r_1 are constructed to the same scale as the distance $BC = s$ between the axes, it is evident that the ratios $\frac{R}{s}$, $\frac{r}{s}$, $\frac{R_1}{s}$, $\frac{r_1}{s}$, etc., obtainable from this diagram are applicable to all distances apart of the axes. The curve BkC, as given in Fig. 5, is not, however, of convenient shape for practical use; it may, therefore, be distorted horizontally, in such a way that the vertical chords remain vertical, which is easily done by transferring the vertical chords of Fig. 5 to a new diagram in which the chords near the vortex k are much farther apart than in the original figure. Figs. 2 and 4 were not, however, obtained by first constructing Fig. 5 and then constructing from it the horizontally distorted figure, but the ordinates of the curve were obtained, as stated above, by calculation, thus avoiding the errors to which all graphical methods are liable.

A curve like that given in Fig. 4 may easily be constructed from the calculated ordinates, particularly if it is placed upon finely lined section paper; and if the curve be constructed on such a scale that the greatest chord $BC = 20$ inches, the results obtainable from it will be sufficiently accurate for all the cases that arise in practice.

French and American Patents. — Laboulaye considers the French people as dupes of the great name of Liberty, and recommends to the consideration of French inventors the example of America. He says that "all nations which do not understand and adopt the American laws are destined to see their industry declining before that of America." The multitude of detailed inventions which have been accumulated in that country, and which are daily continuing to accumulate, in the way of sewing machines, reapers, fire-arms, etc., furnishes sufficient demonstration of the truth of this statement.—*Soc. d'Encour. pour l'Ind. Nat.* C.

EXPERIMENTS WITH THE STEAM-CUTTER OF THE UNITED STATES STEAMSHIP "PENSACOLA."

By Chief Engineer ISHERWOOD, U. S. Navy.

The experiments described in this article were made with the steam-cutter of the United States steamship *Pensacola* by the writer during the time he was Chief Engineer of the Mare Island Navy Yard, California.

The principal object of the experiments was to ascertain the law of the variation of the resistance of the hull in function of its speed; incidental to which there was obtained the maximum power which the machinery could develop, and the corresponding speed of the vessel.

Before proceeding to the experimental data and to the analysis of their results in the cases of the different experimental speeds, there must be given the dimensions, proportions, etc., of the hull and of its machinery, and a description of the manner in which the data were obtained and the results deduced.

The cutter was an open boat constructed at the Mare Island Navy Yard of wood, and sheathed with copper.

HULL.

Extreme length,		38 feet 1 inch.
Length from forward edge of rabbet of stem to after side of sternpost, on load water-line,		35 feet.
Extreme breadth on load water-line,		8 feet 11 inches.
Depth from lower edge of rabbet of keel to top of gunwale at middle of length,		4 feet 3½ inches.
Depth from lower edge of rabbet of keel to load water-line,	Forward,	1·600 feet.
	Mean,	2·175 feet.
	Aft,	2·750 feet.
Depth of keel below the lower edge of its rabbet,	Forward,	0·400 foot.
	Mean,	0·575 foot.
	Aft,	0·750 foot.
Draught of water to load water-line,	Forward,	2 feet.
	Mean,	2 feet 9 inches.
	Aft,	3 feet 6 inches.

Area of greatest immersed transverse section to load water-line,	12·53 square feet.
Area of load water-line,	207·62 square feet.
Area of the immersed external surface of the hull to load water-line,	332·85 square feet.
Displacement to load water-line,	269·00 cubic feet.
Displacement to load water-line,	7·700 tons.
Displacement per inch of draught at load water-line,	0·4953 ton.
Ratio of the area of the greatest immersed transverse section to the area of the circumscribing parallelogram,	0·6461.
Ratio of the area of the load water-line to the area of the circumscribing parallelogram,	0·6653
Ratio of the displacement to the circumscribing parallelopipedon,	0·3963
Ratio of the length to the breadth on the load water-line,	3·9252
Angle of dead-rise at the greatest immersed transverse section,	22½ degrees.
Weight of the hull and its fittings,	6,270 pounds.

Engines.

There are two vertical, direct-acting, non-condensing engines, one placed immediately behind the other, with the axes of the cylinders in the same vertical plane with the axis of the shaft. Each cylinder has a three-ported slide valve, unbalanced, and worked direct from the shaft by means of an eccentric and its rod. The valve of the forward cylinder is upon its after side, and of the after cylinder, upon its forward side. The starting and reversing are effected by turning the eccentrics to stops upon the shaft, by means of a mitre-gear and hand-wheel at the centre of the engines. Both cylinders are bolted to a horizontal flat plate of cast iron that forms their bottoms and is supported upon four cast iron standards which are bolted in turn to a bed-plate secured to the hull—two standards at each end of the bed-plate. The inner sides of each pair of standards are formed into guides for the crosshead. There are but two main pillow-blocks, and they are bolted to, and supported upon, the bed-plate. The forward crank-pin

is overhung. There is one plunger feed-pump, vertical, at the forward end of the bed-plate and supported upon it. This pump is worked direct from a pin in the crosshead of the forward engine. The distance between the axes of the cylinders is 22 inches. The cylinders and their valve-chests are without covering of any kind. The eccentrics are between the engines, and each one is directly below the valve-stem to which its rod is attached. The exhaust steam is delivered into the chimney of the boiler and forms an artificial draught. There is a heater for the feed-water which is heated by the exhaust steam to about 75 degrees Fahrenheit above the temperature of the sea-water whence it is taken.

The following are the principal dimensions:

Number of cylinders,	2.
Diameter of cylinders,	6 inches.
Diameter of piston-rods,	$1\frac{1}{8}$ inches.
Stroke of pistons,	6 inches.
Area of both pistons, exclusive of area of piston-rods,	55.554 square inches.
Space displacement of both pistons per stroke,	0·1919 cubic foot.
Breadth of steam-port,	$\frac{5}{8}$ inch
Length of steam-port,	4 inches.
Area of steam-port,	2·5 square inches.
Breadth of exhaust-port,	$\frac{7}{8}$ inch.
Length of exhaust-port,	4 inches.
Area of exhaust-port,	3·5 square inches.
Diameter of connecting-rods in necks,	$1\frac{3}{16}$ inches.
Length of connecting-rods between centres,	1 foot $2\frac{3}{16}$ inches.
Diameter of crosshead journal,	$\frac{7}{8}$ inch.
Length of crosshead journal,	$1\frac{1}{2}$ inches.
Diameter of crankpin journal of after engine,	2 inches.
Length of crankpin journal of after engine,	$2\frac{1}{2}$ inches.
Diameter of crankpin journal of forward engine,	$1\frac{3}{8}$ inches.
Length of crankpin journal of forward engine,	2 inches.
Diameter of main journals,	$2\frac{1}{2}$ inches.
Length of main journals,	$2\frac{1}{2}$ inches.
Width of eccentric straps,	1 inch.
Diameter of eccentric rods,	$\frac{7}{8}$ inch.
Diameter of feed-pump (single acting and for both engines),	$1\frac{1}{4}$ inch.
Stroke of feed-pump plunger,	6 inches.

Diameter of valves (poppets) of feed pump,	1 inch.
Number of thrust collars,	5.
Inside diameter of thrust collars,	$2\frac{1}{2}$ inches.
Outside diameter of thrust collars,	$3\frac{3}{8}$ inches.
Width of thrust collars,	$\frac{1}{2}$ inch.
Length of crosshead guide-gibs,	3 inches.
Breadth of crosshead guide-gibs,	2 inches.
Thickness of side of cylinders,	$\frac{5}{8}$ inch.
Thickness of plate to which cylinders are bolted,	$1\frac{3}{16}$ inches.
Thickness of bed-plate,	$1\frac{1}{4}$ inches.
Length occupied by the engines in the forward and aft direction of the vessel,	3 feet $6\frac{1}{4}$ inches.
Breadth occupied by the engines in the athwartship direction of the vessel,	2 feet $3\frac{5}{8}$ inches.
Height of the engines above the bottom of the bed-plate,	3 feet 6 inches.

Boiler.

There is one boiler of the locomotive type, with iron tubes in direct continuation from the furnace to the chimney.

The front portion of the boiler is rectangular in plan with a semi-cylindrical top. The length of this portion is 2 feet 10 inches; breadth, 3 feet 6 inches, and height, 4 feet. Upon its top, at its centre, is a cylindrical steam-chest, 18 inches in diameter and 18 inches high. This front portion contains the furnace, 2 feet 3 inches long, 3 feet wide and 2 feet high above the top of the grate. The furnace top is horizontal; the grate is horizontal, and is fired from two doors, one in each side of the front portion of the boiler. The openings for these doors are rectangular, 12 inches wide and $8\frac{1}{2}$ inches high. The bottom of the grate is on the level of the bottom of the front portion of the boiler, and the ash-pit is of cast iron, placed 6 inches below the bottom of the grate.

The remaining portion of the boiler is cylindrical, 3 feet 1 inch in diameter, and 4 feet 4 inches in length, 10 inches of which form the back smoke-box, on the top of which the chimney is placed.

The tubes are eighty-two in number, 2 inches in external diameter, $1\frac{3}{4}$ inches in internal diameter, and $44\frac{1}{2}$ inches in length between tube plates. The least water space between the tubes is $\frac{3}{4}$ inch.

The boiler and steam-pipe are covered with thick felt.

The following are the principal dimensions and proportions of the boiler:

Extreme length,	7 feet 2 inches.
Extreme breadth,	3 feet 6 inches.
Extreme height, exclusive of steam-drum,	4 feet.
Extreme height, inclusive of steam-drum,	5 feet 6 inches.
Number of furnaces,	1.
Length of grate-bars,	2 feet 3 inches.
Breadth of grate,	3 feet.
Area of grate surface,	6·75 square feet.
Number of tubes,	82.
Outside diameter of tubes,	2 inches.
Inside diameter of tubes,	$1\frac{3}{4}$ inches.
Length of tubes between tube-plates,	3 feet $8\frac{1}{2}$ inches.
Water-heating surface in the furnace,	24·75 square feet.
Water-heating surface in the tubes, calculated for inside diameter,	139·29 square feet.
Water-heating surface in the back tube-plate, to 3 inches above furnace top,	4·16 square feet.
Total water-heating surface,	168·20 square feet
Steam superheating surface in the back tube-plate, above 3 inches above furnace top,	1·93 square feet.
Diameter of chimney,	$9\frac{1}{2}$ inches.
Height of chimney above the level of the grate,	11 feet.
Aggregate cross area of the tubes,	1·3700 square feet.
Cross area of the chimney,	0·4922 square foot.
Water space to 3 inches above furnace top,	21·563 cubic feet.
Steam space above 3 inches above furnace top, in boiler proper,	17·723 cubic feet.
Steam space in the steam-drum,	2·650 cubic feet.
Total steam space above 3 inches above furnace top,	20·373 cubic feet.
Ratio of the water-heating to the grate surface,	24·9185 to 1·0000.
Ratio of the steam superheating to the grate surface,	0·2859 to 1·0000.
Ratio of the grate surface to the cross area of the tubes,	4·9270 to 1·0000.
Ratio of the grate surface to the cross area of the chimney,	13·7139 to 1·0000.
Diameter of the blast-pipe (one orifice at base of chimney),	$1\frac{1}{8}$ inches.

Screw.

There is one brass screw. The forward and after edges of its blades, viewed in projection on a plane parallel to its axis, are parallel to each other and perpendicular to the axis.

The thickness of the blades, just above the fillet joining them to the hub, is $\frac{13}{16}$ inch.

The following are the principal dimensions:

Diameter of the screw,	3 feet.
Diameter of the hub,	4 inches.
Pitch (uniform),	5 feet 4 inches.
Number of blades,	3.
Length of the blade on a line parallel to the axis,	0·8889 foot.
Fraction used of the pitch,	0·5000.
Helicoidal area of the blades,	4·8910 square feet.
Projected area of the blades on a plane at right angles to axis,	3·4904 square feet.

Weights of the Machinery.

	Pounds.
Weight of engines,	1460
Weight of line shaft,	195
Weight of stern stuffing box,	46
Weight of stern bearing,	21
Weight of screw,	140
Weight of boiler,	4515
Weight of cast iron ash pan under boiler,	253
Weight of boiler chimney and sundry pipes,	210
Total weight of metal in machinery,	6840
Weight of water in boiler,	1342
Weight of felting, paint, etc.,	48
Total weight of machinery,	8230

Experiments made at the Mare Island Navy Yard, California, with the Steam-Cutter of the U. S. Steamship "Pensacola."

The steam-cutter of the United States steamship *Pensacola*, having been thoroughly repaired—hull and machinery—a set of experiments was made with it at the Mare Island Navy Yard, at different speeds,

but with the same draught of water and trim, to ascertain its resistance at those speeds, the slips of the screw, and the indicated horse-power developed by the engines. These experiments were made during the month of December, 1870.

The base for the experiments, or the course passed over by the cutter during each run, was a straight line 8·955 feet long, as given by the very accurate survey of Mare Island. It extended from the northern side of the dry dock dolphins, or guard piers, to the northern side of the magazine wharf. This base was close under the lee of the high ground of the island. There was no breeze during the experiments, and the water was perfectly smooth. The velocity of the tide varied from nil to three geographical miles per hour.

Seven experiments were made at the speeds, respectively, of $6\frac{1}{2}$, $6\frac{3}{4}$, 7, $7\frac{1}{4}$, $7\frac{1}{2}$, $7\frac{3}{4}$ and 8 geographical miles per hour, as nearly as could be obtained. Each experiment consisted of six runs over the base, three in each direction, and the time of making them was selected when the tide had but little influence. The vessel's speed through the water, during each double run, was ascertained from the time of passing the ranging marks at the ends of the base.

Two indicators were used; one of them was kept permanently in position on one cylinder, and the other on the other cylinder, during the experiments. Each indicator communicated with both ends of its cylinder, and before use was put in perfect adjustment and had its spring tested.

A counter was attached to the screw-shaft, and registered the number of its revolutions.

In making the experiments, the cutter, at the intended speed, was brought opposite one end of the base and then run uniformly to the other, being kept in a straight line by an expert steersman. After passing the last end of the base a sufficient distance, the vessel was turned and the run repeated back in the same manner. The throttle-valve was always carried wide open during the turnings, as well as during the runs, and the steam pressure varied but slightly throughout an experiment, the supply of steam required being always within the capacity of the boiler to furnish, except at the speed of eight geographical miles per hour, which it was very difficult to maintain for even a single run.

From the commencement of each run to its end indicator diagrams were taken as rapidly as possible from each end of each cylinder. The

steam pressure in the boiler, as given by a spring gauge, was noted at the end of every minute.

An observer, stationed always at the same part of the vessel, gave the signal the instant he was opposite the ranges at the ends of the base; and, at the same moment, two other observers took, one the time to a second, and the other the number on the counter. Thus the time of making each run, and the number of revolutions made by the screw in that time, were exactly ascertained.

The results of the experiments will be found in the following table, in which, for convenience of reference, the quantities have been grouped and the lines containing them numbered. For the same reason, the columns containing the quantities for the different speeds have been lettered.

Explanation of the Table.

After the experiments were concluded, and the mean pressure ascertained for each double run from the indicator diagrams taken during that run, a straight base line was divided into abscissæ representing the experimental speeds. From the end of each speed abscissæ an ordinate was erected at a right angle to the base, and on it was laid off, by scale, the indicated pressure belonging to that speed. A fair curve was then passed among the ends of those ordinates, leaving as many on one side as on the other. Again, the slips of the screw having been calculated for each experimental speed, were laid off on the same ordinates, and a fair curve passed among the ends of the ordinates in the same manner as before, leaving as many ends on the one side of the curve as on the other side. From these curves, and for the speeds given on line 1 of the following table, commencing at $6\frac{1}{2}$ geographical miles per hour and increasing by one-quarter of a mile up to 8 miles per hour, there were taken off, by scale, the quantities on lines 2 and line 5 of the table, being, respectively, the slip of the screw in per centum of its axial speed, and the mean gross effective or indicated pressure on the pistons in pounds per square inch, according to the indicator diagrams. Line 3 contains the thrust of the screw, calculated from the quantities on lines 10 and 11, in the manner hereinafter shown under the head of Distribution of the Power. Line 4 contains the number of double strokes made by the engines' pistons per minute, and of revolutions made by the screw in the same time.

They were calculated from the pitch of the screw and the quantities on lines 1 and 2.

Distribution of the Indicated Pressure on the Piston.—Lines 5 to 11, both inclusive, give (line 5) the mean gross effective or indicated pressure on the piston in pounds per square inch for the different experiments, and the remaining lines contain the distribution of that pressure.

Line 6 gives the pressure required to work the engines and shafting —*per se*—when the screw is removed. It was obtained by direct trial.

Line 7 contains the net pressure applied to the shaft, in pounds per square inch of piston. It is the remainder of the pressure on line 5 after deducting that on line 6.

Line 8 contains the pressure absorbed by the friction of the load, in pounds per square inch of piston. It is $7\frac{1}{2}$ per centum of the pressure on line 7.

Line 9 contains the pressure, per square inch of piston, expended in overcoming the resistance of the water to the surface of the screw blades. It is calculated from the quantity on line 16.

Line 10 contains the pressure, per square inch of piston, expended in the slip of the screw. It is calculated from the quantity on line 17.

Line 11 contains the pressure, per square inch of piston, expended in propelling the vessel. It is the pressure which remains after deducting from the pressure on line 7 the pressures on lines 8, 9 and 10.

Distribution of the Engine Power. — Lines 12 to 22, both inclusive, contain the gross-effective horses-power (line 12) developed by the engines, and their distribution. Lines 13 to 18, both inclusive, show the distribution of the power *absolutely*, that is, in horses-power; while lines 19 to 22, both inclusive, show this distribution in per centum of the net horses-power (line 14) applied to the shaft.

The distribution of the indicated or gross-effective horses-power developed by the engines has been calculated in the manner shown below under the head of Distribution of the Power.

The quantities on lines 19, 20, 21 and 22 are the per centum which the quantities on lines 15, 16, 17 and 18 are respectively of the quantity on line 14.

EXPERIMENTS WITH THE STEAM-CUTTER OF THE UNITED STATES STEAMSHIP "PENSACOLA."

By Chief Engineer ISHERWOOD, U. S. Navy.

Table containing the Results of the Experiments made with the Steam-Cutter of the United States Steamship "Pensacola," at the Mare Island Navy Yard, California, in December, 1870.

No. of Line.			a	b	c	d	e	f	g
1		Speed of the vessel per hour, in geographical miles of 6086 feet,	6·50	6·75	7·00	7·25	7·50	7·75	8·00
2		Slip of the screw, in per centum of its speed,	21·450	23·038	24·802	26·833	28·761	30·649	34·248
3		Thrust of the screw, in pounds, calculated from the piston pressure on lines 10 and 11,	272·859	314·348	364·516	427·914	497·109	574·166	650·413
4		Double strokes of Engines' pistons, and revolutions of the screw, made per minute,	157·3792	166·8047	177·0392	188·4532	200·2290	212·5335	224·5679
5	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.	Mean gross-effective or indicated pressure on the pistons, in pounds per square inch,	34·0000	38·7578	44·4897	51·6866	59·5470	68·2997	76·9957
6		Pressure required to work the engine, *per se*, in pounds per square inch of pistons,	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000	2·0000
7		Net pressure applied to the shaft, in pounds per square inch of pistons,	32·0000	36·7578	42·4897	49·6866	57·5470	66·2997	74·9957
8		Pressure absorbed by the friction of the load, in pounds per square inch of pistons,	2·4000	2·7568	3·1867	3·7265	4·3160	4·9725	5·6247
9		Pressure expended in overcoming the resistance of the water to the surface of the screw blades, in pounds per square inch of pistons,	3·4048	3·8228	4·3085	4·8792	5·5072	6·2057	6·9296
10		Pressure expended in the slip of the screw, in pounds per square inch of pistons,	5·6192	6·9509	8·6806	11·0255	13·7250	16·8932	20·1363
11		Pressure expended in the propulsion of the vessel, in pounds per square inch of pistons,	20·5760	23·2273	26·3139	30·0554	33·9988	38·2283	42·3051
12	DISTRIBUTION OF THE ENGINE POWER. ABSOLUTE.	Gross-effective or indicated horses-power developed by the engines,	9·0080	10·8835	13·2596	16·3977	20·0719	24·4370	29·1082
13		Horses-power expended in working the engines, *per se*,	0·5299	0·5616	0·5961	0·6345	0·6741	0·7156	0·7561
14		Net horses-power applied to the shaft,	8·4781	10·3219	12·6635	15·7632	19·3978	23·7214	28·3521
15		Horses-power absorbed by the friction of the lead,	0·6359	0·7741	0·9498	1·1822	1·4548	1·7791	2·1264
16		Horses-power expended in overcoming the resistance of the water to the surface of the screw blades,	0·9018	1·0737	1·2837	1·5484	1·8571	2·2209	2·6200
17		Horses-power expended in the slip of the screw,	1·4887	1·9523	2·5868	3·4970	4·6265	6·0444	7·6124
18		Horses-power expended in the propulsion of the vessel,	5·4517	6·5218	7·8432	9·5356	11·4594	13 6770	15·9933
19	PROPORTIONAL.	Per centum of the net power applied to the shaft, absorbed by the friction of the load,	7·50	5·50	7·50	7·50	7·50	7·50	7·50
20		Per centum of the net power applied to the shaft, expended in overcoming the resistance of the water to the surface of the screw blades,	10·64	10·40	10·14	9·82	9·57	9·36	9·24
21		Per centum of the net power applied to the shaft, expended in the slip of the screw,	17·56	18·91	20·43	22·19	23·85	25·48	26·85
22		Per centum of the net power applied to the shaft, expended in the propulsion of the vessel,	64·30	63·19	61·93	60·49	59·08	57·66	56·41

Manner of Calculating the Distribution of the Power during the Experiments.

To illustrate the manner of calculating the distribution of the indicated or gross-effective horses-power developed by the engines during the experiments, the following detail is given for the experiment in column **a** of the table.

The pressure required to work the engines and shafting, *per se*, being taken at 2 pounds per square inch of pistons, there is thus absorbed (line 13) 0·5299 horse-power.

Deducting from the gross-effective power (line 12) of 9·0080 horses developed by the engines this power of 0·5299 horse, there remains (line 14) the net power of 8·4781 horses applied to the shaft, of which 7½ per centum or 0·6359 horse (line 15) is absorbed by the friction of the load.

The power expended in overcoming the resistance of the water to the surface of the screw blades (line 16), that is, in overcoming their skin resistance, calculated in the ratio of the square of the velocity, and for a value of 0·45 pound per square foot of helicoidal surface moving in its helical path with a velocity of 10 feet per second, amounts to 0·9018 horse.

The powers (0·6359 and 0·9018 horse) absorbed by the friction of the load and expended in overcoming the resistance of the water to the surface of the screw blades being deducted from the net power (8·4781 horses) applied to the shaft, there remain 6·9404 horses-power expended in the slip of the screw and in the propulsion of the hull. And, as the slip of the screw (line 2) is 21·45 per centum of its axial speed, the power expended in it is (6·9404×0·2145=) 1·4887 horses (line 17) leaving (6·9404—1·4887=) 5·4517 horses (line 18) expended in the propulsion of the simple hull.

Collecting the foregoing, we have the following distribution of the power, namely:

	Horses-power.	Per cent.
Gross-effective or indicated power developed by the engines, ...	9·0080	
Power required to work the engines and shafting, *per se*, ...	0·5299	
Net power applied to the shaft, . . .	8·4781	or 100·00

Power absorbed by the friction of the load, .	0·6359 or	7·50
Power expended in overcoming the resistance of the water to the surface of the screw blades, .	0·9018 "	10·64
Power expended in the slip of the screw, .	1·4887 "	17·56
Power expended in the propulsion of the vessel, .	1·5717 "	64·30
Totals, . . .	8·4781 or	100·00

Thrust of the Screw.

The thrust of the screw during the foregoing performance can be calculated from the piston pressures on lines 10 and 11, the sum of which reduced in the ratio of the length (one foot) of the double stroke of the pistons to the pitch ($5\frac{1}{3}$ feet) of the screw, and multiplied by the aggregate number of square inches in the two pistons, will give the thrust of the screw in pounds; or, what is the same, the statical resistance of the vessel in pounds at the experimental speed.

In the case of experiment **a**, the sum of the piston pressures on lines 10 and 11 is 26·1952 pounds per square inch, and, as the aggregate area of the two pistons is 55·554 square inches, the thrust of the screw, or resistance of the vessel, is $\left(\frac{26{\cdot}1952}{5\frac{1}{3}} \times 55{\cdot}554 = \right)$ 272·859 pounds (line 2).

Results of the Experiments.

The mean steam pressure in the boiler during the experiment recorded in column **a** of the preceding table was 50·42 pounds per square inch above the atmosphere; during the experiment recorded in column **b**, 57 pounds; during the experiment recorded in column **c**, 64 pounds; during the experiment recorded in column **d**, 72 pounds; during the experiment recorded in column **e**, 79·75 pounds; during the experiment recorded in column **f**, 87 pounds; and during the experiment recorded in column **g**, 94 pounds.

§ The temperature of the feed-water before entering the heater was 55 degrees Fahrenheit; and when entering the boiler, 130 degrees Fahrenheit.

§ The resistances of the hull at different speeds varied in a much higher ratio than the square of the speed, as will be seen by the following comparison, in which they are given both proportionally for the square of the speed, and also proportionally as ascertained by experiment and deduced from the quantities on line 3 of the preceding table.

Column of the table.	Speeds of the vessel in geographical miles per hour.	Squares of the speeds, proportionally.	Experimental resistances, proportionally.
a	6·50	1·0000	1·0000
b	6·75	1·0785	1·1525
c	7·00	1·1599	1·3359
d	7·25	1·2440	1·5683
e	7·50	1·3311	1·8219
f	7·75	1·4216	2·1043
g	8·00	1·5147	2·3837

The power of the speed of the vessel, in which its resistances increased from 6·50 geographical miles per hour to each of the experimental speeds, is as follows:

Speed of the vessel in geographical miles per hour.	Power of the speed in which the vessel's resistances increased.
6·50	———
6·75	3·7571
7·00	3·9090
7·25	4·1203
7·50	4·1906
7·75	4·2300
8·00	4·1829

The power of the speed of the vessel, in which its resistances increased for each experimental increment of speed of one-fourth of a geographical mile per hour, is as follows:

Speed of the vessel in geographical miles per hour.	Power of the speed in which the vessel's resistances increased from one experimental speed to the next greater.
6·50 } 6·75 }	3·7571
6·75 } 7·00 }	4·0756
7·00 } 7·25 }	4·5708
7·25 } 7·50 }	4·4190
7·50 } 7·75 }	4·3990
7·75 } 8·00 }	3·9225

According to the above, the power of the speed in which the vessel's resistance gradually increased from one experimental speed to the next greater, gradually rose until it became a maximum at the speed of 7·25 geographical miles per hour, from which to the speed of 8·00 geographical miles per hour it gradually declined.

During the different experiments the trim of the vessel changed with each change of speed, and in a very marked manner; the bow rising and the stern falling with each increase of speed. Notwithstanding the sharpness of the bow, the vessel, even at her lowest speed, carried a wide and high wave before her.

At the lowest speed there was a hollow or marked depression in the water a little abaft the stern, followed immediately by a corresponding wave or elevation of water above the general level, and with each increase of speed this hollow became deeper and deeper, and farther and farther from the stern, while the wave which followed it became higher and higher, and also more and more distant. At the highest speed the gunwale at the stern of the cutter was below the general level of the water, so that the persons sitting in the stern sheets appeared to an observer on shore to be standing waist-deep in the water, the cutter's stern being invisible.

There was not only this great alteration of the vessel's trim observed, but also that she began at medium speed to rise bodily above her mean draught of water when at rest, the bow becoming disproportionately high out of water.

The above phenomena, no doubt, exist for all vessels, be their size and form what they may, when their speed exceeds the limit at which their resistances increase in the ratio of the squares of the speeds; but this limit being farther and farther removed as the hull has greater length and finer form, is not in large and well-modeled vessels reached with the ordinary speeds of practice; but when even such vessels are driven beyond the speed of about 12 geographical miles per hour the appearances described make their influence felt.

The first cause of this marked change of trim with the increasing speeds of the cutter was the shortness of her after body comparably with her draught of water aft. Now, the water replacing at the vessel's after body that which was displaced at her fore body, comes from the plane of greatest pressure, which is the plane passing horizontally through the lower edge of the rabbet of the keel, and it rises solely by the force of gravity, the weight of the adjoining column of

water measured from the plane referred to up to the water level, forcing it upwards, and it rises with the same velocity no matter what may be the vessel's speed. But, as the vessel's speed increases, the ascending mass of water cannot reach the after body in time to support it in the position it had when at rest, and, consequently, this after body must drop until it does meet the ascending mass of water, and obtains thereby sufficient floatation. The greater the speed of the vessel, the farther the after body must drop, and with each dropping the resistance of the vessel must increase. As long, however, as the speed of the vessel is such, relatively to her length of after body and draught of water aft, that the ascending mass of water can reach the after body in time, there will be no dropping at the stern, and the vessel's resistance up to that speed will be in the ratio of the squares of the speeds.

The phenomena, as regards the bow, are influenced by the length of the fore body relatively to the speed. The displaced water rises vertically (that being its line of least resistance) along the sides of the fore body, and spreads out over the general level, the height of the rise and the area for the spreading out being measured, other things equal, by the length of the side of the fore body. When the speed of the vessel is increased to such a degree that the wave of translation does not move swiftly enough to keep out of the way of the vessel, the latter rises upon it as upon an inclined plane, and emerges bodily above her mean draught of water when at rest, thus offering a less external wetted surface and a less greatest immersed transverse section to be driven by the engines. In this way the decreased power of the speed in which the resistance of the vessel increased at the higher rates of speed may be explained.

The resistance of the hull is composed of two parts; one, that of her external immersed or wetted surface; the other, that of her form abstracted from this surface resistance. The first may be called her resistance in function of surface, and the last her resistance in function of form. The first may be approximated with reasonable accuracy by calculation; the last must be ascertained experimentally.

The experiments with the *Pensacola's* steam-cutter allow this separation of these two resistances to be made in her case, and each to be ascertained for the different experimental speeds of the vessel.

The speed with which the watery molecules glide over the wetted surface of the hull is less than the speed of the vessel, owing to the

inclination of her lines to her longitudinal axis, and, in the case under examination, these two speeds may be taken to be in the ratio of 0·974 to 1·000. Assuming the wetted surface not to change in area during the experiments, it is 332·85 square feet, each square foot of which, when moving with the velocity of 10 feet per second, has the resistance of 0·45 pound, which resistance increases and decreases with the square of the velocity. Calculating with these data the resistance of the external immersed or wetted surface of the hull for each experimental speed, and deducting it from the resistance of the hull at each of these speeds (line 3 of the table), the remainder will be the resistance in function of form. And it is evident that, as the resistance in function of surface varies with the square of the vessel's speed, all the increased resistance above that ratio must be due to the form alone.

In the following table will be found the results of these calculations, the resistance of the vessel in function of surface and in function of form being given separately:

Speed of the vessel in geographical miles per hour.	Total resistance of the vessel in pounds.	Resistance of the vessel in function of surface alone, in pounds.	Resistance of the vessel in function of form alone, in pounds.	Per centum which the resistance of the vessel in function of surface is of her total resistance.	Per centum which the resistance of the vessel in function of form is of her total resistance.
6·50	272·859	171·484	101·375	62·85	37·15
6·75	314·348	184·965	129·383	58·84	41·16
7·00	364·516	198·445	166·071	54·44	45·56
7·25	427·914	213·590	214·324	49·91	50·09
7·50	497·109	228·402	268·707	45·95	54·05
7·75	574·166	243·846	330·320	42·47	57·53
8·00	650·413	259·723	390·690	39·93	60·07

The power of the speed of the vessel in which its resistances in function of form alone increased for each experimental increment of speed of one-fourth of a geographical mile per hour, is as follows:

Speed of the vessel in geographical miles per hour.	Power of the speed in which the vessel's resistances in function of form alone increased from one experimental speed to the next greater.
6·50 } 6·75 }	6·4745
6·75 } 7·00 }	6·8719
7·00 } 7·25 }	7·2727
7·25 } 7·50 }	6·6660
7·50 } 7·75 }	6·3047
7·75 } 8·00 }	5·2812

The quantities on line 22 of the table show the proportion of the net horse-power developed by the engines applied to the screw shaft, which was utilized in the propulsion of the vessel. They consequently represent the relative economic efficieny of the screw, referred to the net horse-power, at the different speeds of vessel. Had the resistances of the vessel been in the ratio of the squares of its speeds, the quantities on line 22 would have been equal; the decrease of the screw's efficiency with the increase of the vessel's speed, is due to the fact that the resistance of the vessel increased in a higher ratio than the square of its speed, while the resistance of the watery fulcrum to the screw blades increased only in the ratio of the square of the number of their revolutions in equal time, and that the number of these revolutions, *ceteris paribus*, is in the direct ratio of the speed of the vessel; that is to say, if the resistance of the vessel is as the square of its speed, the number of revolutions of the screw in equal time will be as the speed of the vessel.

As the resistance which the screw experiences from its watery fulcrum, other things equal, is as the square of the number of its revolutions in a given time, and as the vessel's speed is as the number of revolutions made by its screw in equal time, provided the resistance of the vessel increased as the square of its speed, then the resistances of the screw and of the vessel, in this case, would increase in the same duplicate ratio of the speed, and the slip of the screw would consequently remain constant, and its economic efficiency undergo no change.

But if the vessel's resistance increased in a higher ratio than the square of its speed, the resistance of the screw remaining in the ratio of the square of its revolutions in equal time, then the slip of the screw would increase with increased speed of vessel, and become greater and greater as that speed became greater and greater, and the screw would have, in consequence of these increasing slips, less and less economic efficiency.

The loss of economic efficiency by the screw, primarily caused by increased slip, includes not only the loss due to the increased slip, *per se*, but also that which is due to the increased resistance of the water to the screw surface, or, in other words, to the increased skin resistance of the blades, because, in order that the vessel make a given speed, more revolutions of the screw will be required in equal time with the increased slip of the screw, whose corresponding surface loss will be as the squares of the number of revolutions made in equal time.

Fall of a Market Roof in Paris.—On a cold night of last December, when the thermometer stood at —15° (5°F.), the metallic roof of St. Martin market suddenly fell. It was built upon rigid supports and seems to have been sufficiently strong. The cause of the fall was therefore a mystery, and the French engineers are discussing the subject with much interest. They very generally agree in regarding the rigidity of the supports as a defect and in thinking that the extremities of every beam should be allowed sufficient lateral play to prevent any injurious effect, either from contraction by cold or from expansion by heat.—*Chron. Indust.* C.

Temperature of Frozen Lakes.—F. A. Forel has made a series of observations on the Swiss lakes, similar to that of Buchanan at Loch Lomond. He finds that the limit of the superficial chill is much greater than has been hitherto supposed, extending in some cases even to the depth of 110 metres (120·3 yards). The penetration of the cold into the upper layers takes place very gradually and progressively. It does not appear to be accomplished either by convection or by mechanical mixture under the action of waves and currents, but may perhaps be connected with conductibility and radiation. Observations extended over an interval of forty days showed a great uniformity of temperature, but at no time was the uniformity complete throughout the whole depth of the lakes.—*Comptes Rendus.* C.

EYE-MEMORY.

A Lecture delivered before the Franklin Institute March 29th, 1880,

By CHARLES G. LELAND.

There are few people who have ever reflected on the fact that every one has within him a faculty which, if properly developed, would completely change our system of education by increasing to an incredible degree our power of mental acquisition. This faculty I term Eye-memory. It has already been recognized by writers as Visual Representation, Imaginary Appearance and Volitionary Pseudopia, each term expressing the subject in a manner characteristic of its inventor.

We are all in the habit of hearing the utterances of other people during our waking hours, of reading books and catching sounds. But unless we deliberately set ourselves to work to get these utterances, ideas or sounds *by heart*, we only retain a vague general impression of them. Getting by heart, or "memorizing," is effected by concentrating or intensifying the attention and by frequent repetition. When this is extensively practiced in youth, the mental memory is thereby greatly strengthened or improved, while the thinking faculties are, by the same process, stimulated and disciplined. This is, in fact, the real aim of most early education. Only the vulgar and ignorant believe that the acquisition of knowledge and the learning certain definite quantities of mathematics, languages or history alone constitute an education. A wiser man knows that it is the training of the mental powers which forms the true result of culture.

Now just as the mind may be instructed and disciplined by mere *reading*, that is to say, indirectly taught by symbols called letters, so it may be directly supplied with facts or phenomena by eye-memory. This is the impressing by will on memory things which we have *seen*. Thus, for instance, if you close your eyes and try to recall the exact appearance of any object with which you have been familiar, you will find great difficulty in doing so. As a rule children possess this faculty to a much higher degree than grown people. But if you put the object before you and look at it frequently you will succeed in learning it, so as to be able to read it at will. The longer you study it with a determination to remember it, the more vividly will its color and gen-

eral appearance come before you. It is possible, with practice, to develop this faculty so as to produce the most extraordinary results. The absent friend may be recalled at will, so that his form appears as clearly defined as in life, and by frequent exercise you may surround yourself with familiar or imagined scenes which appear like nature. This power may be extended to books. You have all heard of people who "cipher" from imagined visual numerals, and of others who had the power to recall sheet-music, and to play from the notes thus brought before the eye. I have read of a Scotch preacher who said that, while apparently preaching without notes, he was really reading from a manuscript which he saw mentally before him. He could see even the marks of punctuation. And this use of the faculty of visual representation occurred whenever he had written a sermon and read it carefully before going into the pulpit. I venture to believe that it would be possible, with practice, to recall any page of anything which we had read, or rather seen, and in like manner to get by eye a gallery of pictures. As it is, we may appreciate and thoroughly enjoy works of art. But unless we deliberately exert our will, and intentionally impress them on the memory with much trouble, they will not recur to us as real things. They will not come when we call to them. Why is it that, after going through a gallery, we remember a few pictures and forget others? Simply because we have unconsciously, through *interest*, brought our memory to bear upon the few. Had we been trained from childhood to use this visual memory in the same manner in which we are trained to exercise mental memory, we could probably recall at will any object which we had *once* willed to remember.

There have been, however, many persons who have acquired this desirable art. Thus we are told that Nicolas Loir, an eminent French painter and engraver, when in Italy, devoted his time to contemplating the works of the great masters, his eye-memory becoming so retentive by practice that he was able to sketch the pictures which had pleased him most.

I have met with a coachmaker, also a draughtsman, who, after seeing any vehicle pass by, however rapidly, can draw and color it in detail to the minutest ornaments, and who can do the same of any object which he saw even forty years ago, if he had taken pains at the time to learn it. I know a lady who, while in Europe, memorized many galleries of pictures and shop windows. Francis Galton has completely established the fact that there are in England hundreds of

accountants who carry out sums in arithmetic entirely by visual representation. This power is popularly admired as a rare gift; in reality it is irrepressible in a few, involuntarily developed in others, and is innate in us all.

The importance of developing this faculty has suggested itself to many artists. Thus Couture advised his pupils to let the eye rest for an instant on passers-by in the street, and then attempt to draw them. I have seen this put in practice with perfect success, and have heard from others authentic experiences of it. The various stages of the process were extremely curious and interesting. At first only a hat, and perhaps the general appearance of an arm, or a leg, can be caught, but in a few hours the expression of the whole figure is seldom missed. No one who had not practiced this, or seen it done, would believe how rapidly the observation and memory are developed by this kind of "flash photograph" drawing, or what an air of vivacity and motion is imparted to the figures. I recommend the practice of it specially to those who intend to draw for the illustrated newspapers. They are often obliged to make notes or hasty sketches of moving masses of men, and they perforce acquire a certain degree of eye-memory. But we need only study the details of most of their pictures of crowds to see that it is not highly developed with them.

While collecting facts on eye-memory, I wrote to Dr. Oliver Wendell Holmes for information, and I need not say that I was not disappointed, as I received from him his work entitled *Mechanism in Thought and Morals*, in which I find that the subject of "pictured thought," as a branch of conscious mental action, has not escaped his attention. He has ingeniously illustrated it "by the panorama of their past lives, said by people who have escaped from drowning to have flashed before them." This actually happened to Dr. Holmes himself, as it did to my brother Henry Perry Leland. I also received from Dr. Holmes the work on Visions, by Dr. Edward H. Clarke, edited by himself. In this book that which the author calls "the power of the will to produce objective *pseudopia*," or to see that which is not before the eyes, is treated almost exhaustively, as regards the physical explanation of the faculty. "Sight," says Dr. Clarke, "is not a function of the eyes, but of the brain." "There is a way by which volition plays with its utmost energy upon the angular gyrus, or some other centre, and drives its machinery into action. If this can be accomplished, vision is accomplished. When we consider that there is no part of the body which

cannot be affected somewhat by volition, it would be singular if the visual ganglia should be the only ones withdrawn from the influence and authority of the will." In illustration of the fact that the will can reproduce what the eye has seen, Dr. Clarke cites the case of a gentleman who, being fond of statuary, succeeded, after a few trials, in producing visions of statues, and even in imagining new ones. This author has, in my judgment, completely established the fact that every object making an impression on the brain, or visual apparatus, leaves an organic trace there, which may be reproduced at an indefinite period afterwards by cerebral action. I find in fact, in the *Visions* of Dr. Clarke, as in the *Mental Physiology* of Dr. William B. Carpenter, a sound basis for, and a perfect confirmation of, all that I claim as regards eye-memory.

Goethe tells us, in his work *Aus meinem Leben, Wahrheit und Dichtung*, that having one day seen ideally a picture by Van Ostade, he cultivated the faculty so as to afterwards produce at will subjective copies of pictures and works of art. De Quincy recognized and distinctly describes the faculty of recalling or creating visions at will. In fact, the illustrations that this power exists are so numerous, and the physiological explanations of it are so copious and satisfactory, that it would be impossible to bring them within the limits of the longest lecture. But I have not been able to ascertain that any writer has ever contemplated the deliberate cultivation of volitional vision as an aid to every branch of intellectual education and of art. I do not know that any one has contemplated the possibility of its being introduced into schools and taught in classes. I believe myself that entire books will be thus memorized with little effort, that all which the eye has seen the trained will will revive, and that, far beyond all this, imagination aided by volition, will evoke from the mystic brain cells, where they lie by millions upon million *perdu*, all manner of beautiful forms, and create from them at will others more beautiful. Would not this be a new life for every man and woman of culture? Would not, in such a life, much that is mean and much which now degrades us, vanish like mists before sunshine? Yet all this is just as physically possible as that sounds and sights should be transmitted by telegraph and preserved *ad infinitum*.

But to return to the application of eye-memory to art. When I was in St. Petersburg, Russia, I found that great attention was there paid, in the School of Design, to free-hand drawing. The happiest

results were secured by telling the pupils to study a given object for ten minutes, and then, the object being removed, to draw it. Mr. John Sartain has told me that, in his youth, his teacher of drawing, the celebrated Varley, would place the image or picture to be copied in one room and tell the pupils to work in another, allowing them to go, from time to time, to look at it. I understand that the Russian method has been practiced in some schools in Philadelphia. It cannot be denied that when the model is always directly before the pupil the latter seldom observes anything carefully, nor does he study the relations of the details of form, light and shade and color as he would when memorizing. I have come to the conclusion that it requires full half an hour for most people to get by heart or eye the simplest object in the world—that is to say, a billiard ball, with all its lights and shadows. But when the artist is compelled to get the whole object actually by heart, he studies the relations of the different qualities or details, and develops in his mind higher and much more vigorous powers of observation. Thus trained, his eye sees more at the first glance, he becomes self-reliant, he does not depend on the thousand times repeated, half-observant, glance.

We have all heard of Blake, the artist, who saw spectral delusions, or imaginary phantoms, so vividly that he used to copy them. Once, when he was thus painting Charles the First, as he believed, from life, for a friend, he stopped in his work. "Why do you not go on?" asked his friend. "Because William the Conqueror has just stepped in the way, and before him," answered Blake, very seriously. I will tell you a story upon this story, out of my own experience. Once, in London, after a dinner party, I was in our host's library, with a French gentleman, one of the guests. Finding that he was evidently well informed in art matters, and as there were several volumes of Blake's pictures on the table, I showed them to him. He had never seen anything of Blake's before, so I told him what I could remember of that extraordinary man, and how he used to paint from spectral delusions. "But he must have been mad," said the French gentleman. "Not at all," I replied; "he was almost a genius—*enfin mônsieur, c'était un Doré manqué*—he was almost a Doré." The point of this remark was not apparent to me till some time afterwards, when I learned, to my astonishment, that it was to Monsieur Doré himself that I had addressed it!

Monsieur Doré is an artist of wonderful invention and of great

fertility, but I know of none in whom the public have perceived so precisely what his limits are. We know what he knows by heart, and what his eye-memory has mastered, and when he is drawing on the old stock figures. Had he cultivated the faculty of visual memory in youth to perfection, he would have avoided such mannerism as we observe. For it evidently would fill the mind with facts or objects which would be in the highest degree suggestive and inspiring. We have all found in our own experiences that we remember certain scenes with great vividness when certain persons or certain pleasurable associations are connected with them. We remember the brow of the hill, the amber sunset sky, the foliage like dark bronze against it, because some young lady, perhaps, caused us to remember it. Our will was unconsciously exerted. This association of scenes with persons and events has become part of the stock-in-trade of the modern novelists. We all know how a certain scene was indelibly branded in the heroine's memory—how, to the end of her days, the ticking of the clock and the patterns in the carpet all rose up whenever anything recalled that awful hour. Yet there is a basis for curious or valuable observation in all this. We have in it a confirmation of my assertion that there are causes which will strengthen and develop to an unusual degree our memory of objects.

I have said that the power of memory by sight may be increased to a degree of which we have no conception, and also that young people, as De Quincy declares, possess this power more than those advanced in life. To prove this I will read to you a passage from the life of the celebrated French conjuror, Robert Houdin. It was this passage which first attracted my attention to eye-memory, and caused me to reflect on the indefinite degree to which it may be extended in education especially in that of artists. I must premise that this famous juggler had invented a trick, called Second Sight, which I saw performed by him and his son in Paris in 1848. He found that to effect this it was necessary to cultivate not merely his mental memory to an extraordinary extent, but to remember things as they *appeared*. The trick consisted effectively of getting by heart, or remembering, the exact appearance of every object which might by any possibility be brought by anybody to his exhibition. The son of Houdin, a boy, was blindfolded; the father, in another part of the hall, looked at the object, and his son promptly described it. There was, of course, a

method of secretly signalling from one to the other; this is sometimes effected by a telegraphic wire in the floor, worked by the foot.

"I resolved," says Robert Houdin, "on making some experiments with my son Emile, and in order to make my young assistant understand the nature of the exercise we were going to learn I took a domino, the 4—5 for instance, and laid it before him. Instead of letting him count the points of the two numbers, I requested him to tell me the total at once.

"'Nine,' he said.

"Then I added another domino, the 4—3.

"'That makes sixteen,' he said without any hesitation.

"I stopped the first lesson here; the next day we succeeded in counting at a glance four dominoes; the day after, six: and thus at length we were enabled to give instantaneously the product of a dozen dominoes.

"This result obtained, we applied ourselves to a far more difficult task, over which we spent a month. My son and I passed rapidly before a toy-shop, or any other displaying a variety of wares, and cast an attentive glance upon it. A few steps further on we drew paper and pencil from our pockets, and tried which could describe the greatest number of objects seen in passing. I must own that my son far excelled me, for he would often write down forty objects, while I could scarcely recall thirty. Often feeling vexed at this defeat, I would return to the shop and verify his statement; but he rarely made a mistake.

"My male readers," continues Monsieur Houdin, "will certainly understand the possibility of this, but they will recognize the difficulty. As for my lady readers, I am convinced that they will see nothing remarkable in it, for they daily perform far more astounding feats. Thus, for instance, I can safely assert that one lady seeing another lady pass at full speed in a carriage, will have had time to analyze her toilette, from her bonnet to her shoes, and be able to describe not only the fashion and quality of the stuffs; but also say if the lace be real, or only machine-made. I have known ladies to do this. This natural or acquired faculty among ladies, but which my son and I had only gained by constant practice, was of great service in my performances; for, while I was executing my tricks, I could see everything that passed around me, and thus prepare to foil any difficulties presented me."

Having thus cultivated observation and memory, the juggler and his son proceeded to render themselves familiar with an incredible variety of small objects. Conjecturing, as the result afterwards proved, that they would have many curiosities or antiques, such as old coins, arms and jewelry, brought to them to describe, they visited many museums. It is very evident, not merely from Houdin's own account, but from what was practically shown in his public exhibitions, that in a few months the father and son added incredibly to their stores of knowledge or information, retaining a vivid picture of every object which they deliberately *willed* to remember. Having developed the eye-memory by hard work up to such a point that they could see a thing almost as clearly as if the original object, or indeed whole rows of such objects were present, they found that the faculty, once well acquired, kept itself in action with ordinary practice. They now learned very readily the characters or letters of many languages, such as Greek, Hebrew, Chinese, Russian and Turkish, the names of all surgical instruments, and of many other technical objects. Walking through a library, they could recollect the appearance of whole rows of books, with the titles on their backs.

There can be no question that Robert Houdin was an unusually clever man, of great powers of observation and quickness, which had been greatly improved by the practice of juggling. Yet, making every allowance for his remarkable talent, I am all the more convinced that his experiences and discoveries indicate that the faculty of an indefinite development of eye-memory exists in every one, especially in the young, and that it will at some future day enter largely into education, and form its physical basis. Anybody can verify for himself the simple fact that any object may be *eye-memorized* by special study. No casual observation, unaccompanied by the *will* to remember, will enable us to do so much as can be effected by determined effort. We may see a face a thousand times, and yet in most cases we cannot recall it so accurately for artistic purposes as if we had deliberately *studied* it a dozen times with that object. But it is especially to art students that I commend the practice of it. When you are copying an object, it makes a very great difference indeed whether you look very carefully at the original, and into its every condition, or merely *glance* at and set down what you half observe and *half* imagine. For it is a fact that in the most accurate copying we draw largely upon our imaginations. We are copying, let us say, a vase or

a book, and, having secured a general conception of its proportions, we proceed by speculation or fancy more than we are ourselves aware of. As I have already said, when the model is *directly before* the pupil, he does not generally study it carefully as a whole, nor observe or memorize the proportions of its different parts. He copies it simply part by part. Now I would urge that the wonderful power of eye-memory, or of recalling objects exactly as they appear, should be deliberately cultivated, especially in the young. I think that by practicing as Robert Houdin practiced with his son, and by competing as they competed, very remarkable results would very soon be obtained. The pupils need not be taken about to shop windows; shelves and tables, at home, with objects arranged on them, would answer the purpose for primary lessons.

The next step, which goes beyond all that Robert Houdin conceived, just as it transcends the ordinary object-teaching of the Kindergarten, is the photographing some one object, as, for instance, a statue, so indelibly upon the eye and memory by the exercise of close observation, will, and renewal in the memory, that it can even serve as a visible model. In children who cannot draw, the faculty may be developed by examining them on maps and the relative boundaries of States. This is oft en done now, but when I was at school maps were indeed hung before the scholars, and we were required to learn them, yet it never entered into our teacher's head, or into our own, that the whole map might have been learned in less time by visual memory—by looking at and closing our eyes, and recalling at first the different colors of the different States, and then their relative position, and finally their shapes. The method by which this process of getting, for instance, a map, by eye, and even the peculiar processes by which different people will attempt it, are well described by Dr. Haslain (Sound Mind), who in turn is commented on by Dr. A. L. Wigan in his Duality of Mind (p. 313–14).

But it would be well if children could all draw, since drawing and memory are great mutual aids. I quite agree with Froebel, the Kindergarten philosopher, that it is highly important that a child should acquire some facility in drawing even before he learns to read and write, since the representation of actual things should precede the representation of signs and words. In connection with the subject of object-teaching and drawing, Emily Shirreff, the author of the *Intellectual Education of Women*, observes that "it would be curious to

inquire how much of the loose thinking, the hazy perception of truth, which characterize the majority of even the educated portion of mankind, might be traced back to the absence of any *definite* impressions made in childhood in connection with the instructions given to them. Outside the school-room they acquire definite impressions, but they are acquired at random, and may be wholly wanting in accuracy."

(To be continued.)

ELECTRIC TIME TELEGRAPHS.

Read before the Franklin Institute at its meeting March 17th, 1880.

By LOUIS H. SPELLIER.

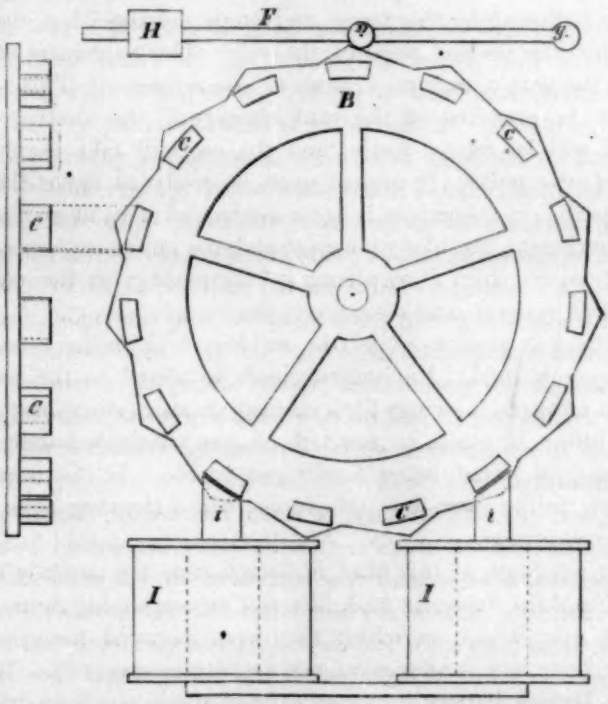
There are two classes of electric clocks—the electric clock proper, or the electro-magnetic pendulum, and the electro-magnetic time telegraph. The former has been to this day more of a scientific curiosity than a useful invention. It is only the latter, the electric time telegraph, which has proved a partial success. As the name indicates, they are instruments which receive the time telegraphed. For this purpose a standard clock, which in certain intervals of time completes or breaks the circuit of a galvanic battery, is needed. Although many and various in construction, they all resemble each other very closely in their most essential parts.

They mainly depend upon the action of one electro-magnet and one armature. The latter is a piece of iron, which is attracted by the poles of the electro-magnet, when the telegraphing clock completes the circuit of a galvanic battery connected with it. As soon as the clock breaks the circuit again the armature is repelled to its former position by a spring or weight. This movement of the armature turns a wheel which drives time-indicating machinery, and is repeated as often as this machinery requires to indicate the time of the clock, which makes or breaks the electric circuit.

Such instruments work very well, if the action of the armature is needed about once every minute, but if repeated every second or two, then its imperfections become apparent. The movement of the armature is sudden and rapid. With a lightning-like velocity the armature moves toward the magnet, and is checked instantaneously in its rapid progress just at a time when nearest the magnet and most powerfully

attracted. Naturally the wheel, which receives its moving impulse directly from the armature, moves with the same rapidity and is checked as suddenly. Those sudden checks, offered to the armature and wheel, show their damaging results in a comparatively short time, and soon impair the correctness of such instruments.

In correcting these destructive evils I never succeeded completely until an entirely new system suggested itself to me, and of which the accompanying figure shows the principle.



Instead of one armature I have a number of them, *C*, fastened at equal distances around the circumference of wheel *B*. With *B* on the same axle another wheel is fastened, having as many cogs, of the peculiar shape shown in the figure, as *B* has armatures. *F* is a lever with its oscillating centre at *g*, and has a pulley, *D*, which presses against the circumference of the wheel *B* by the weight *H*. *I i* is the electro-magnet. The electro-magnet is connected with a gal-

vanic battery, of which the circuit is closed and opened by the oscillations of a pendulum. The instrument acts in the following manner:

When the current of the galvanic battery is closed, the armature *C* will be attracted by the electro-magnet, and move *A* and *B* in the direction indicated by the arrow, and stops as soon as *C* is directly over it. When in this position the pulley *D* rests upon the upper part of the cog, and presses against it. As soon as the electric current is disconnected, and the electro-magnet discharged of its magnetism, the pressure of the pulley *D* against the cog moves *B* in the direction indicated by the arrow, and stops moving when the pulley has reached the deepest point of the cog. This movement of *B* has brought the next armature, *C*, near to the magnet *i*. This armature will now be attracted at the next closing of the electric current. Then *B* will be moved again, and the cog will take the first position, and the pulley *D* presses upon it, ready to move the wheel as soon as the electro-magnet is again discharged of its magnetism; and so on, alternately, the electro-magnet and the pulley will interchange their action, and keep *B* revolving in the manner as the pendulum of the clock connects and disconnects the electric current.

The object in view, to avoid the sudden check to the armature, is hereby accomplished. No sudden check is offered to the armature, but when attracted it swings for a moment in short vibrations over the magnet before it comes to rest. It is comparatively noiseless in its movements, its sound being hardly perceptible. In this respect it is very much unlike other time telegraphs, whose clapping noise is their constant companion.

A time telegraph of this kind in operation at the monthly meeting of the Franklin Institute had, like the accompanying figure, fifteen armatures (the wheel on which they were mounted measuring five inches and one-half in diameter), and two electro-magnets. With six cells of a Daniell Battery it proved to have ample power to drive four dial works for dials 5 feet 6 inches in diameter. It may have as many electro-magnets as it has armatures. This is a circumstance of some importance, since it will increase its driving capacity with each additional electro-magnet without adding materially to the size of the instrument.

Whatever the reason may be, there is no doubt that, to this day, the time telegraphs have not received such notice as they really deserve.

Their service can be more useful and general than is mostly admitted. If we consider that we can control by one correct time-piece just as many time telegraphs to indicate true time as necessity or fancy requires, providing there is battery power enough to move them, we have reason to believe that they still may come into general use in hotels and public buildings, where true and equal time in every room of the house is desirable.

But there is still another field of great importance for the time telegraph.

It has been a problem of great perplexity, to this day, with the most ingenious minds of the horological world, how to construct clocks which will overcome the effects of wind and storm beating against the exposed clock dials of public clocks. It is true, Remontoires and Gravity Escapements have been invented to remedy the evil, and clocks may go better with them than without them; but, nevertheless, all these ingenious contrivances have almost as many evils, on account of their complication, as they are designed to avoid. And here it is where the time telegraph has its future. A well-regulated clock, kept at a place of even temperature, will show but very little variation of time. If such a clock controls a time telegraph adapted for tower or public clocks, it will show the time with only such slight variation as will hardly be noticed by the public.

One objection raised against time telegraphs—the use of the galvanic battery—can be an objection no longer. Its treatment is now almost generally understood since it has found its way into so many branches of business of every-day life. There is little room left to doubt that when the utility of the time telegraphs is once recognized it will receive more deserved notice and be brought into more general use; and the time may not be far distant when the subtle power of electricity will regulate all our better class of tower or other public clocks.

International Postage Stamps.—France and Belgium have entered into negotiations for the establishment of a joint postage stamp. If the plan is carried out the payment of small sums could be made between the two countries in stamps. Moreover, in letters requiring answers, stamps could be enclosed for the reply, a thing which is now impossible.—*Chron. Indust.* C.

GAS ENGINES.

Gas engines have lately been brought so prominently before the public at the different exhibitions of gas appliances, held by gas companies in various parts of the country, that a few words about their history, and a short description of those at present in the market, may prove of interest to our readers.

It is not our intention to go deeply into the principles of gas engines, but to give a short *résumé* of what has been done to develop these engines from the earliest up to the present time. That the prejudice that originally existed against this class of engines is being rapidly overcome is evident by the variety of purposes to which they are now being applied. This prejudice was now doubt originated by the failures of the early engines, before the combustion and combination of gases had been thoroughly investigated. The feeling was also greatly increased by the jealousy of small steam engine makers, who saw in these new engines formidable rivals to their own productions, and naturally cried down the new comers.

The first patent for what may really be called a gas engine was taken out in the year 1791 by one John Barber. It is described in his specification as "a patent for using inflammable air for the purpose of procuring motion." Coal, wood or oil, or any other combustible matter was placed in a retort, and the smoke or vapor collected and cooled in a reservoir. It was thence conveyed by an air pump to a compressor or regulating bellows which supplied an exploder. Common air was then injected in due proportion, and the explosion was then effected by means of a light. Here then is roughly the principle of some of the most modern gas engines.

In the year 1794, Thomas Mead obtained a patent for an apparatus by means of which, when air, gas or other elastic fluid came in contact with ignited combustible matter, or felt the power of heat in a confined space, it became decomposed and expanded by the heat, and by the evolution and expansion of its component parts acted on a piston and exerted power. His specification also shows how he obtained a vacuum under his piston which the atmosphere pressed on and forced it back. This is in part the principle on which the Otto and Langen atmospheric engine acted, which is described further on in this paper.

The principle of the hydrocarbon engine, manufactured by George Brayton, of America, and by Messrs. Thompson, Sterne & Co., of Glasgow, was partly anticipated by Robert Street, who in 1794 obtained a patent for an apparatus from which he proposed to obtain motive power by means of a few drops of spirit of tar or turpentine being poured upon the heated bottom of a cylinder, and thus being converted into vapor. Air was then sucked into the cylinder, and an explosive mixture formed, which when ignited forced up the piston, and thus by suitable mechanism gave motion to machinery.

The first mention we find of automatically governed engines is in a patent granted in the year 1833 to Lemuel Wright. The specification mentions that governors were applied to the engine to regulate the quantities of gas or air supplied to the cylinders. Various patents were granted between this time and 1860, which appear to have been more or less improvements of the afore-mentioned patents, but none came into practical use. In 1860 we find a communication from J. Lenoir was granted a patent for an invention consisting of the application and use of an inflammable gas mixed with a proper proportion of atmospheric air, and ignited inside a cylinder by means of electricity. The explosion thereby produced, acting on a piston, produced motion, which was transmitted to a driving shaft. The supply of gas was regulated by a suitable governor. In the same year Pierre Hugon obtained a patent for an engine somewhat similar in principle to the above. These, we believe, were the first two gas engines which came into anything like practical and general use. Later on—in 1860—Pierre Hugon obtained a provisional protection for improvements in his former specification. This applied to an improved method of lighting his charge, for which purpose he used red-hot platinum wires. These engines were made double-acting, and great difficulty was experienced in keeping the cylinders cool. They were found to be uneconomical in practice, and never came into very extended use. A few of them may, however, still be found at work in various parts of the country.

The first patent taken out in connection with the well-known atmospheric gas engine of Messrs. Otto & Langen, of Deutz, near Cologne—afterwards manufactured by Messrs. Crosley Brothers, of Manchester, the present makers of the "Otto" engine—was in the year 1863, and was improved in 1866. In this engine an explosive mixture of air and gas drives up a light piston attached to a rack in gear with a spur wheel on the fly-wheel shaft. This wheel is not connected with

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The first patent for what may really be called a gas engine was taken out in the year 1791 by one John Barber. It is described in his specification as "a patent for using inflammable air for the purpose of procuring motion." Coal, wood or oil, or any other combustible matter was placed in a retort, and the smoke or vapor collected and cooled in a reservoir. It was thence conveyed by an air pump to a compressor or regulating bellows which supplied an exploder. Common air was then injected in due proportion, and the explosion was then effected by means of a light. Here then is roughly the principle of some of the most modern gas engines.

In the year 1794, Thomas Mead obtained a patent for an apparatus by means of which, when air, gas or other elastic fluid came in contact with ignited combustible matter, or felt the power of heat in a confined space, it became decomposed and expanded by the heat, and by the evolution and expansion of its component parts acted on a piston and exerted power. His specification also shows how he obtained a vacuum under his piston which the atmosphere pressed on and forced it back. This is in part the principle on which the Otto and Langen atmospheric engine acted, which is described further on in this paper.

The principle of the hydrocarbon engine, manufactured by George Brayton, of America, and by Messrs. Thompson, Sterne & Co., of Glasgow, was partly anticipated by Robert Street, who in 1794 obtained a patent for an apparatus from which he proposed to obtain motive power by means of a few drops of spirit of tar or turpentine being poured upon the heated bottom of a cylinder, and thus being converted into vapor. Air was then sucked into the cylinder, and an explosive mixture formed, which when ignited forced up the piston, and thus by suitable mechanism gave motion to machinery.

The first mention we find of automatically governed engines is in a patent granted in the year 1833 to Lemuel Wright. The specification mentions that governors were applied to the engine to regulate the quantities of gas or air supplied to the cylinders. Various patents were granted between this time and 1860, which appear to have been more or less improvements of the afore-mentioned patents, but none came into practical use. In 1860 we find a communication from J. Lenoir was granted a patent for an invention consisting of the application and use of an inflammable gas mixed with a proper proportion of atmospheric air, and ignited inside a cylinder by means of electricity. The explosion thereby produced, acting on a piston, produced motion, which was transmitted to a driving shaft. The supply of gas was regulated by a suitable governor. In the same year Pierre Hugon obtained a patent for an engine somewhat similar in principle to the above. These, we believe, were the first two gas engines which came into anything like practical and general use. Later on—in 1860—Pierre Hugon obtained a provisional protection for improvements in his former specification. This applied to an improved method of lighting his charge, for which purpose he used red-hot platinum wires. These engines were made double-acting, and great difficulty was experienced in keeping the cylinders cool. They were found to be uneconomical in practice, and never came into very extended use. A few of them may, however, still be found at work in various parts of the country.

The first patent taken out in connection with the well-known atmospheric gas engine of Messrs. Otto & Langen, of Deutz, near Cologne —afterwards manufactured by Messrs. Crosley Brothers, of Manchester, the present makers of the "Otto" engine—was in the year 1863, and was improved in 1866. In this engine an explosive mixture of air and gas drives up a light piston attached to a rack in gear with a spur wheel on the fly-wheel shaft. This wheel is not connected with

the shaft, but, by means of a ratchet wheel or friction clutch mechanism, allows the piston to fly up free of the fly-wheel shaft when the explosion takes place; and on a partial vacuum being formed under the piston by means of the condensation of the products of the explosion, the piston descends by the pressure of the atmosphere. The friction clutch is then thrown into gear, and imparts motion to the fly-wheel shaft. This engine was found to be extremely economical in practice, only 21 cubic feet of gas per indicated horse-power per hour being consumed. Upwards of 4000 engines were made on this principle, and a large number are at present doing good work.

In January, 1874, a communication from Frederick Gilles, of Cologne, was granted a patent for improvements in motors worked by gas, as follows: An elongated cylinder open at one end is provided with two pistons, a loose one, and a "working" one, connected in the usual way to a crank on the main shaft, which is provided with a fly-wheel. Assuming the working piston to be at the extremity of its inward stroke, on turning the fly-wheel it is drawn towards the outer end of its stroke, followed by the loose piston, until the latter is stopped by a crosshead on the rod attached to it. The working piston continuing its movement causes a partial vacuum behind it, in the space between it and the loose piston. The charge of mixed gas and air is then admitted into this space and is exploded. The force of the explosion causes the working piston to move onwards to the end of its stroke, and at the same time forces the loose piston to move quickly in the opposite direction. A vacuum is formed between them, which draws up the working piston, while the loose piston is held fast at the top of the cylinder by suitable mechanism. When the working piston nears the top of its inward stroke, the loose piston is released, and falling rapidly expels the products of combustion at the exhaust valve, and the action is then repeated. As will be seen from the above description, the engine is made with the cylinder vertical. The English licensees were Messrs. L. Simon & Son, of Nottingham, who made several of these engines.

The engine bears a remarkably close resemblance to, and, in fact, may almost be said to have been anticipated by a patent taken out in May, 1864, by Francis Wenham, for "an engine worked by explosive mixtures." The specification describes an engine whose action appears to have been precisely similar to the above. We are not

aware, however, that an engine made according to his specification was ever brought out.

In May, 1876, Messrs. Otto & Langen, of Deutz, took out a patent for a gas engine, which, after several modifications and improvements, resulted in the production of the now well known "Otto" silent gas engine, which has since come into such extended use. Indeed, there are few large towns in England where many of these engines may not be found at work. The principle on which this engine works opened an entirely new field to scientists and engineers, and it may be looked on as the forerunner of an entirely new class of gas engines. This was the first engine in which a gradual expansion of the charge of gas and air was utilized, thus insuring great economy in working. By introducing a diluent of atmospheric air, or other neutral gas in sufficient quantity, with a small charge of coal gas, the highly explosive nature of a purer mixture of oxygen and hydrogen, or air and coal-gas, is reduced within an easily manageable compass. The charge is compressed in the cylinder, and then, on a light being admitted, is exploded, or, to speak more correctly, "burned," and this ignition expanding the neutral remainder of the charge, a well sustained and but gradually diminishing pressure is brought to bear on the piston throughout the length of the stroke, and a total absence of shock to the working parts is thus insured. We have seen diagrams taken from these engines at work, and they show a beautifully regular expansive curve, falling gradually from 160 lbs. at the commencement of the stroke, to about 40 lbs. on the opening of the exhaust valve. A chief advantage that this engine possesses over others in the market is that it performs in one cylinder what others are compelled to do in two, namely, the compression and ignition of the charge, the cylinder being used alternately as a pump and a motor. The fly-wheel consequently makes two complete revolutions for one charge of gas when the engine is doing full work. On starting the engine, the first out stroke of the piston sucks in the charge of gas and air, which is compressed by the first inward stroke of the piston; the charge is then fired, and the piston consequently forced outwards again, and the second return stroke, performed by the momentum of the fly-wheel, expels the products of combustion at the exhaust valve, and the operation, as above described, is repeated. The engine is horizontal and single-acting, the charge being admitted behind the piston. The amount of gas used is in proportion to the work taken out of the engine, and is regulated by an extremely sensi-

tive governor. The consumption of gas by the "Otto" when doing full work is about 22 cubic feet per indicated horse-power per hour.

Messrs. Louis Simon & Son, of Nottingham, took out a patent in 1877 for "Improvements in Atmospheric Gas Engines." Atmospheric air is compressed by a pump and stored in a reservoir, from which it is withdrawn and utilized in fixed quantities by suitable valves under control of the moving mechanism after the engine is first started. With the specification is a drawing of a vertical engine with the pump alongside the cylinder. In this arrangement the bed-plate is a hollow casting, and is used as a reservoir for the compressed air. In February, 1878, Messrs. Simon took out a patent for an engine with inverted vertical cylinder and pump, motion being imparted to the crank shaft by means of an oscillating beam and connecting rod. The invention consists in the introduction of steam into the cylinders of gas engines. Steam is expanded by the heat of the cylinder, and by the heat developed by the combustion of a mixture of gas and air, and thus adds power and economizes gas. The engine is somewhat the same in principle as the "Otto," inasmuch as the charge of gas and air is compressed, and ignited under compression, but differs from it in that this engine ignites its charge once for every revolution, and by means of the pump, forces the combustible mixture into the cylinder during a part of the stroke. Eventually the beam was dispensed with, and the engine is now made in the form fully illustrated and described in No. 1203*, vol. xlvii, of *The Engineer*. It has a novel institution in the shape of a boiler placed on top of the explosion cylinder in which the waste gases are used to raise water to boiling point, and thus, as already pointed out, slightly aid in driving the engine.

It is stated that a pressure of 40 lbs. per square inch is attained in the boiler after the engine has worked a short time. The engine is made single-acting, and is virtually a combination of a gas and steam engine, as it has two elements acting together to produce motion, viz., combustion and expansion of a mixture of gas and air and steam, generated by the heat of the exhausted gases. The diagrams taken from the engine are good. In an improved design of this engine, patented in 1878, it is shown as an ordinary vertical engine with the cylinders below. A hand force pump is added for facilitating starting. This engine is now also made horizontal, and was recently exhibited at an exhibition of gas appliances held in Nottingham.

* January 7th, 1879.

An engine recently shown at an exhibition of gas appliances, held at Bradford, and manufactured by Messrs. S. Clayton & Co. of Bradford, was patented by them in 1878. This engine bears a striking resemblance to the "Otto." It is a horizontal engine, but uses a separate pump underneath the cylinder for drawing in a regulated supply of air, gas or vapor, and forcing the same into the cylinder through a port regulated or controlled by a valve. The gas supply is regulated by a governor, and the charge of air may be either compressed or used at atmospheric pressure. The engine can be made either single- or double-acting, and differs from the two foregoing engines in that the charge may be fired every stroke, or each alternate one, as desired. It also has no slide valve, but instead, uses one of a conical rotary construction, somewhat like an ordinary cock. Having no data, we cannot speak as to the consumption of gas by this engine.

Richard Hellewell, of Blackburn, in 1878, improved on a patent taken out by him in 1877, for a vertical engine with two pistons in one cylinder. When the charge is ignited the loose piston is driven upwards by the force of the explosion, and is held at the top of the cylinder by suitable mechanism. A vacuum is formed, and the other piston, to which is attached the connecting rod, is drawn upwards by means of the vacuum. The loose piston is released when the fast one has reached the top of its stroke and then follows it down the cylinder, and the operation as above described is repeated. It is needless to remark on the similarity this engine presents to others already described.

In December, 1875, Edwin Alexander patented a communication from Alexis de Bischop, of Paris, for a gas engine. The engine is made with a very long, narrow cylinder, so as to accommodate to as great an extent as possible the speed of piston to the explosive force of the mixture of air and gas. The increase in the speed of piston thus obtained affords a longer expansion of the burnt gas. The stroke is made ten or more times the diameter of the piston in length. A piston valve, worked by an eccentric on the fly-wheel shaft, is used in this engine, in lieu of the usual slide valve. The action is as follows: On turning the fly-wheel by hand at starting, the piston is moved upwards, at the same time drawing in a charge of gas and air. When the piston has traversed one-third of its stroke, the admission of gas and air is cut off by the raising of the piston valve, and the charge is ignited. The force of the explosion drives the piston the remainder of its stroke.

The piston is caused to descend by the momentum of the fly-wheel gained during the ascent of the piston after the explosion. At the same time, the products of combustion are forced out of the cylinder at the exhaust valve. The piston, again ascending, draws in a fresh charge, and the action is repeated. The engine is vertical and single-acting, an explosion occurring at every revolution of the crank shaft. The chief peculiarity of the engine is that no lubricant is required, nor water for cooling purposes, the latter being accomplished by radiation. The consumption of gas being very large, the maximum power offered is not equal to half a horse, or thereabouts. No governor is applied. These engines are made in England by Mr. J. Andrews, of Stockport.

In 1878 Mr. Dugald Clark patented an engine now made by Messrs. Thompson, Sterne & Co., of Glasgow, and exhibited at the recent agricultural show at Kilburn. The engine is horizontal and single-acting. The air-pump is placed alongside the cylinder, and the whole engine presents a neat and compact appearance. Air and gas are admitted to the pump by means of a valve, when its piston moves outwards and becomes mixed therein; and on the return inwards of the pump piston, the mixture passes through a lift valve into an intermediate chamber or reservoir constituting the back end piece of both cylinders. The igniting arrangement in this engine is novel. A small piece of platinum wire in the cylinder valve is used for this purpose, which having once become heated, remains so; for each time the mixture passes on its way into the cylinder, and is exploded, the platinum receives as much heat as is necessary to make up for its loss otherwise, and is thus always kept at a red heat sufficient to ignite the charge. In this engine, as in those previously described, the gas and air are used under compression, water also being circulated round the cylinder to keep it cool. In this case a small centrifugal pump is used for the purpose. A governor acts on the gas regulator valve, controlling the supply. The consumption of gas in this engine is stated by the makers to be but 15 cubic feet per indicated horse-power per hour.

In having thus traced the development of the gas engine down to the present time, we have been debarred by want of space from mentioning every patent which has been taken out in connection with them, many of which have never advanced beyond mere provisional protections. We have therefore merely touched on the more important patents, or those in connection with the various engines at present before the public. But that there is a grand future for this

class of engines no one will deny; and that the public now feel that they can place confidence in the engines is evinced by the number of new firms which of late have taken up their manufacture. In many cases, where hitherto small steam engines have been exclusively used, gas engines are rapidly taking their places. One very great point in their favor is that no extra insurance premium is generally required. Another great advantage held by gas engines over steam engines is the fact of being able to get full power whenever required at a moment's notice, without the time usually wasted in getting up steam. Moreover, as soon as the gas engine is stopped consumption of fuel ceases, and no steam has to be kept up in case the engine is wanted only at intervals. The electric light scare undoubtedly acted most beneficially for gas engine makers. Apart from the fact that gas engines were in many cases put down to drive the electric light machines, it brought gas companies to their senses, and caused them to supply, in some cases, better and cheaper gas. This was an extra inducement to people to lay down gas engines which had not previously existed. Undoubtedly the fact that gas engines have now proved themselves really reliable motors has induced various trades, where hitherto hand-power has been almost entirely used, to put down a safe and economical motive power, as a means of developing and extending their trade. In many cases power is required where the high insurances on steam boilers have hitherto precluded their use. Gas engines, then, at once step in to overcome the difficulty. With them their is no smoke, no water, no coal to get in, nor ashes and cinders to remove, no boiler to blow up, or at least to insure; no waiting to raise steam or waste in keeping it ready, no stoker, and no cumbrous boiler setting. That some difficulties yet remain to be overcome may be admitted, but that these do not hinder their practical utility is now well proved by the many thousands of them already found in use scattered over all parts of the world.—*Engineer.*

Condensers of Tempered Glass.—G. Ducretet says that recipients of tempered glass, when employed like Leyden jars, are capable of receiving, without being fractured, a strong charge of electricity, and, consequently, of giving condensed sparks of a power far superior to those which are ordinarily obtained. Plates of tempered glass can be employed in the same manner. Leyden jars of very minute dimensions give remarkable results.—*Comptes Rendus.* C.

New Electro-Magnet.—Chambrier increases the power of electro-magnets by augmenting the extent of active surface at the extremity of the core and of the oscillating armature. He indicates various ways of doing this, which are all nearly equivalent in effect; he hollows the core and gives to the armature a projection fitting into the cavity, or he attaches the projection to the core, making it fit a cavity of the armature. A battery of eight or ten elements is as efficient, with his arrangement, as fifteen elements with an ordinary electro-magnet. The residuary magnetism is not increased; it appears rather to be weakened.—*Comptes Rendus.* C.

Torrential Deltas.—Desor gives his assent to the general conclusion of the geologists who have examined the recent terraces of the Cornici, and who regard them as ancient deltas. Instead of being horizontal, they are inclined under an angle of 12 to 20°, like the abundant collections of conglomerates which are found at the mouth of the principal rivers of ancient Liguria. He considers all deltas of this kind as due to the action of mountain torrents, and recommends a careful distinction in future geological study between the torrential deltas and the deltas of large rivers. He believes this distinction is as important in all cases as that which has been established between marine and lacustrine deltas.—*Comptes Rendus.* C.

Experiments upon Rails.—Tresca has published the results of experiments on the flexion of iron and steel rails, between the limits of elasticity and rupture. They show that for these two metals, in their ordinary industrial condition, the coefficient of elasticity is nearly the same and may be designated by the equation $E. = 21 \times 10^9$, thus confirming his special experiments in 1857 and 1859 upon Swedish irons and the cementation steels which are made from those irons. He finds that the limit of elasticity, for a given bar, may be extended in proportion to the energetic actions to which it has been previously submitted, and that the elastic limit may be pushed almost to the point of rupture without the coefficient of elasticity having varied in any perceptible degree. The metal, when it comes from the workshops, is in a manifest state of instability, which disappears only by use; it becomes, by means of the actions to which it is successively submitted in its employment, more homogeneous and more elastic, but at the same time a little more flexible.—*Soc. des Ingen. Civ.* C.

Magnetic Writing. — Prof. Thompson, of Bristol, has lately made an interesting observation in regard to an application of magnetism. He takes a thin plate of hardened steel and writes upon it with a magnetized iron style, thus communicating a tolerably permanent magnetism to the parts of the plate which are covered by the writing. If fine iron filings are sprinkled upon the plate and the plate is then held perpendicular, so as to remove the loose filings, the writing becomes visible upon the magnetized portion. The experiment may be repeated, at pleasure, for an indefinite period. — *Fortsch. der Zeit.* C.

Induction Estimate of the Mechanical Equivalent of Heat. — From the law of conservation of energy it follows that the work which an electric current in a conductor is able to perform must be equivalent to the work which is required to excite the same current in the same conductor through induction. This consideration induced von Waltenhofen, when he was engaged in some experiments suggested by the theory of electro-magnetic machines, to undertake a determination of the mechanical equivalent of heat by means of electricity. The result of his researches was about one-half per cent. less than Joule's equivalent. — *Ann. der Phys. und Chem.* C.

Relation between Pressure, Temperature and Density of Saturated Vapors. — Winkelmann finds a relation which may be expressed by the following equation:

$$t_n = (a + b)\frac{d_n}{n_d} A - a.$$

t_n is the temperature of the saturated vapor under the pressure of n atmospheres; d_n the density of the saturated vapor under the same pressure, the density of air being regarded as the unit; d the density of the vapor as deduced from the molecular weight; A a constant magnitude which is the same for all vapors; a and b two constant magnitudes which depend upon the nature of the vapor. The equation, which holds good for the vapors of all fluids that have been investigated, contains only two constants which vary for different fluids. These constants have a simple significance, for example, if $n = 1$, $t = b$; *i. e.*, b denotes the temperature at which the vapor has the tension of a single atmosphere; if $n = o$, $t_0 = a$; *i. e.*, at the temperature $-a$ the fluid begins to change into vapor. — *Ann. der Phys. und Chem.* C.

Elasticity of Chrome Steel.—In his experiments upon the hydrodynamometer, Pellat found that the elastic resistance of chrome steel could be pushed to a much higher figure than any other metal which he tried, without passing the limit of elasticity.—*Ann. des Ponts et Chauss.* C.

Density of Liquefied Oxygen.—Prof. J. Offret thinks that Pictet was too hasty in assigning a density to liquefied oxygen equivalent to that of water. He points out errors of calculation which reduce the result by Pictet's first method to ·8655, and wholly invalidate his second method. He regards his own figures, however, as merely provisory, and as probably below the true value. Further investigations may perhaps still prove the correctness of Dumas' prediction, that water and liquid oxygen have equivalent densities.—*Ann. de Chem. et de Phys.*

Applications of the Hydrodynamometer. — De Perrodie reports a series of experiments which were undertaken to determine the exact value of the coefficient of the hydraulic dynamometer. Among the uses to which he finds it especially applicable is the measurement of the intensity of the wind. In the same way as balances are made for all purposes, from the most delicate determinations of chemical analysis to the most ponderous weighings in mechanical workshops, hydrodynamometers may be constructed of all degrees of strength, from those which are used in physical laboratories for the minute study of hydrodynamic laws to those which engineers would employ for gauging the force of water at the greatest depths.—*Ann. des Ponts et Chauss.* C.

Crookes' Vacuum. — In his experiments upon radiant matter Crookes required a vacuum of a millionth of an atmosphere. It was obtained by a combination of Geissler's and Sprengel's mercurial exhausters, and measured by McLeod's gauge. Warren de la Rue estimates that the gauge will correctly record a vacuum of one fifteen-millionth of an atmosphere. Precipitated sulphur was used by Crookes in order to absorb the mercurial vapors; metallic copper, reduced from its oxide, to absorb the sulphurous vapors, and sulphuric anhydride to absorb the vapor of water. A small radiometer was employed to show the progress of the vacuum, and a Plücker tube for a similar purpose, the spectrum of the electric spark changing with the degree of rarefaction.*Ann. de Chim. et de Phys.* C.

Passivity of Iron.—Concentrated or fuming nitric acid does not corrode iron; on the contrary, when iron is dipped into it it acquires the singular property of resisting the attacks of diluted acid. The fuming acid is said to render the iron passive. Dumas first called attention to this fact in his lectures. It was afterwards studied by the elder Becquerel, de la Rive and others, who offered various hypotheses to account for the phenomenon. It was commonly thought that a film formed on the surface of the metal, consisting either of an oxide or of an insoluble nitrate, which constituted a sort of varnish and thus prevented any further attack. L. Varenne has found that the passivity depends in great measure upon the degree of condensation in the metal, but that in all cases it may be overcome by shocks, and even by extremely feeble vibrations which are excited by the action of an electro-magnet. Moreover, a current of gas, even though very feeble, usually destroys the passivity. Varenne finally concluded that the phenomenon was entirely due to a gaseous film on the surface of the metal, and his belief was confirmed by finding that the passivity ceased entirely in vacuum. He thinks that the film consists principally of gaseous nitric oxide. He proposes to extend his researches, in order to find what are the causes which lead to the formation of the film, and what is the nature of the influences which afterwards maintain its adherence.—*Ann. de Chim. et de Phys.* C.

Book Notices.

EXPERIMENTS ON THE STRENGTH OF WROUGHT IRON AND OF CHAIN CABLES. By Commander L. A. Beardslee, U. S. N.; revised and abridged by Wm. Kent, M. E. John Wiley & Son, New York. 1879. 8vo, pp. 119.

This very valuable work comprises the details of experimental inquiry into the physical and chemical properties of rolled iron, especially as relates to cable iron, being a portion of the report to the United States Government of the Board appointed to test iron, steel and other metals. It is scarcely possible to overrate its usefulness as a guide for future investigations or for the correct determination of the properties of iron for the purposes immediately considered, or other practical application. The abridgement of the full report is restricted in the main and in all essential regards to the omission of

tabular matter which is purely corroboratory to what has been retained, so that this work presents for record a full account of the proceedings of the committee of the Board referred to.

Even a summary of this report would far surpass the limits of a book notice, and it is only to recommend it as an example of positive knowledge available at all future times to the mechanical engineer that any expression of merit can judiciously be made. Still, some particular conclusions may be noticed as of interest to the general reader. It is demonstrated that a studded link cable is, contrary to all previous authority, no stronger than one with open links of the same weight of iron in the round, and much weaker than one with open links when the dimension of iron in the round gives equality of weight to equal length of cable. Again, it is shown that any test of a cable which strains the iron above its elastic limit, so far from adding to the severity by the detection of faults, is an actual source of weakness in developing incipient defects. B.

LABOR AND CAPITAL: ALLIES NOT ENEMIES. By Edward Atkinson. 32mo. New York: Harper Brothers. 1880.

This little volume contains the substance of the argument lately presented to the Congressional Committee on Labor, of which A. S. Hewitt is chairman. Of the great importance of the subject there is not the slightest doubt, and as it involves questions upon which there is a great variety of opinion—concerning money, legal tender, the tariff, a national excise system, the bank question, and perhaps the greatest of all, the problem of National or State interference in the pursuits of citizens for shortening the hours of work, promoting education, and attempting to compass the material welfare of special classes by means of legislation—it is worthy of all the time and thought that can be expended upon it.

The author truly observes that the great forces named, Labor and Capital, are one and the same in essence—allies, not enemies—and that the titles we give them only serve to distinguish the effort of the past that has been saved and not expended from that which is now exerted; but whether these forces shall be brought into conflict or not depends in great degree upon the capacity of those who frame the laws under which the production and distribution of wealth are conducted. We cordially commend the volume to the attention of our readers. N.

OUR HOMES. By Henry Hartshorne, M. D. 18mo. Philadelphia: Presley Blakiston. 1880.

We would be pleased if the carefully prepared volumes of the American Health Primers could be found and read in every home, each additional one seeming more admirable than those that have preceded it. No one could be fitted for the task of writing a volume upon "Our Homes" more eminently than the late Professor of Hygiene in the University of Pennsylvania; and in the different chapters, after some introductory matter of a valuable kind, we have the situation of the house and its construction discussed, the important questions of light, warmth, ventilation, water supply, drainage and disinfection. In that on workingmen's homes a brief account is given of the Building Associations of Philadelphia, where by paying a moderate sum a month the artisan becomes the owner of the property, and which has made Philadelphia so peculiarly a city of homes for all classes. It is one of his highest aims, and in which he nearly always succeeds. The volume, like all in the series, is well printed, and has quite a number of illustrations for the moderate price it is sold for. N.

THE FIELD ENGINEER. By Wm. Friedley Shunk. D. Van Nostrand. 1880. 8vo, tucks.

One of the pocket books for railroad work in the field, "prepared with special reference to the wants of the young engineer." The elementary portion of this work is in one sense prepared in admirable form for practical use. It is set out to be "a compendious exposition of those mathematical truths and methods which the young engineer *must* become familiar with from the beginning. Such familiarity may not be had from the work itself, but it is sure to come to those who will *study* to acquire it from sources readily to be ascertained. Learning backwards is a sure way to learn, but it has the defect of giving more of special than of general knowledge. Any young engineer, however, who will have mastered the truths set down for him to become familiar with will have attained competency in his profession for all ordinary requirements of American practice.

There are given problems covering the demands of daily work in the field, with concomitant tables of reference in computation. B.

Franklin Institute.

HALL OF THE INSTITUTE, April 21st, 1880.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 117 members and 28 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that 14 persons were elected members of the Institute at their last meeting. He also read the following letter:

"PHILADELPHIA, March 27th, 1880.

"WILLIAM P. TATHAM, ESQ., *President of the Franklin Institute of the State of Pennsylvania for the promotion of the Mechanic Arts.*

"DEAR SIR,—Please accept, in behalf of the Institute, the enclosed one thousand dollar ($1,000) certificate of the 6 per cent. untaxed loan of the city of Philadelphia, due in 1895.

"It is my wish that this amount shall be re-invested, when paid off, in such manner as may be directed by the Board of Managers, and the annual income be used in aid of such apprentices to the machine business as may need assistance to enable them to receive the instruction given by the Institute in mechanical drawing. These pupils to be selected in such manner and under such regulations as may be made by the Board of Managers of the Institute.

"Very truly yours,

"B. H. BARTOL."

The Secretary reported that Mr. Lewis S. Ware had a short time ago presented to the Library a valuable set of the "Annales du Genie Civil," and that now he had given a set of the "Annales Industrielles," and the acquisition of such serials and works obtained from the Bloomfield Moore Trust Fund, from Mr. A. E. Outerbridge's lectures, and by purchase from time to time by the Institute, was fast making the Library one of the most important in the country for technical works relating to science and the mechanic arts.

The following donations have been received since the last report:

Accounts of the Operations of the Great Trigonometrical Survey of India. Vols. 2, 3, 4.
From His Excellency the Viceroy and Governor General of India in Council.

Letters of Registration of Inventions. Australia, 1855 to 1876.
Through Robt. Grimshaw, Ph. D.

Catalogue du Ministère de l'Instruction publique des Cultes, etc. Vols. 1—3, in 5 parts. Section Belge. Catalogue Officiel des Œuvres d'Art, etc. From the Minister of Public Instruction, France.

Reports on the Departments of the Exhibition of Pennsylvania State Agricultural Society. Sept., 1879. From C. Henry Roney.

Improvement in Steam Boilers. By Ogle & Burnett, Washington, Ohio.

Annuaire de l'Academie Royale des Sciences, etc., de Belgique. Vol. 46. From the Academy.

Second and Third Annual Reports of the State Board of Health of Massachusetts, 1871 and 1872. From the Board.

History of the Pacific Guano Company. From the Company.

Register of Commissioned, etc., Officers of the Navy of the United States. January, 1880. From the Navy Department.

Almanaque de la Gaceta Industrial. 1880. From the Publisher.

New Jersey Geological Survey. Annual Report of the State Geologist for 1879. From the State Geologist.

Subject Index of Publications of the United States Naval Observatory, 1845—1875. By E. S. Holden.
From the U. S. Naval Observatory.

Report of the Meteorological Office of the Dominion of Canada. By G. T. Kingston. 1878. From the Office.

Croton Water Supply and its Extensions.
From the C. E. Club of the North-west.

Annual Report of the Adjutant-General of Pennsylvania, 1879.
From Jas. W. Latta, Adj.-Gen'l.

American Institute of Mining Engineers. List of Officers, etc. etc.
From the Institute.

Seventh Annual Report of the New Jersey State Board of Agriculture for 1879. From the Board.

Memoir of Isaac Hays. By Alfred Stillé.
From College of Physicians.

American *versus* English Locomotives.

Annual Report of the St. Louis Mercantile Library Association. 1879. From the Association.

Circulars of Information of the Bureau of Education. No. 5. 1879. From the Bureau.

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Mr. Hugo Bilgram read a paper on "Isochronous Governors for Steam Engines," suggested by the discussion at the last monthly meeting, when there appeared to be some difference of opinion as to whether governors could be made isochronous. Mr. Bilgram said that the question could, in fact, be answered both ways, according to the meaning attached to the word isochronous. The periodical admission and action of the steam have a more pronounced action on cut-off than on throttle governors, and the former only were considered by Mr. Bilgram. The cut-off governor exerts its influence upon the admission of steam only at the moment of the cutting off, and then loses all control over the working capacity of the engine until the corresponding moment of the following stroke. During the intervening period the fly-wheel (including all its equivalents in moving parts) regulates the speed within certain limits. Most governors are designed to remove, as rapidly as possible, any cause for a change of speed. The conditions may be examined by supposing the load of an engine, running at a uniform speed, to be suddenly changed, say increased, immediately *after* the moment of cutting off. The work developed during the following half turn of the fly-wheel will be the same as if no change had occurred in the load; but, as the fly-wheel must supply the power to do the increased work, its speed will be reduced accordingly. This reduction during the first period will be a measure or gauge of the amount of adjustment required, and being made by the governor the working capacity of the engine for the second period will be increased as much as the energy of the fly-wheel has been reduced, the increase of load will be balanced, and the speed will continue uniformly, but at a less rate than originally. The change was graphically represented and explained. Such regulation can be accomplished by the common or stable pendulum, if its degree of sensitiveness is suited to the size of the fly-wheel. This relation may be thus expressed: The *sum* of the energy of the moving parts (fly-wheel, etc.) and of the work developed per stroke of the engine should be a *constant* quantity.

If the change of the load should happen at a later moment than immediately after the cutting off, the governor will only effect a partial correction during the first period, and will require two periods to complete the correction. This, also, was graphically represented. The usual objection to this kind of governor is the permanent change of speed following a permanent change of load, but Mr. Bilgram thought this less serious than frequently represented, and pointed out how the remedy generally suggested—an increase of the theoretical sensitiveness of the governor—is invariably a failure.

It appeard from this that isochronous governors theoretically not allowing a change of speed, could not handle a steam engine. The question then arises, "Can a governor be made that, in case of a change of load, though theoretically admitting a temporary departure from the normal speed, will eventually restore the original speed?" This question Mr. Bilgram answered in the affirmative, and proceeded to show how the purpose could be effected by making a governor which should adjust the valve gear somewhat more than necessary to meet the change of load and then withdraw the surplus adjustment by the time normal speed was restored. Diagrams were presented to show that inertia governors would not effect this purpose, nor a combination of an isochronous resistance governor with an inertia governor. The cause of the failure of the parabolic governor was traced to its lack of stability, and Mr. Bilgram pointed out that if a one-speed pendulum could be converted temporarily into a stable pendulum, a successful governor would be produced. A spring reacting upon the balls of a one-speed governor would make the pendulum permanently stable, but by substituting for the spring a slightly leaking air cushion the desired governor would be obtained. Mr. Bilgram then showed how the size of the air cushion (in the form of a cylinder and piston) should be calculated, and said that such a governor would accomplish the desired purpose, that is, produce an over-adjustment, and then retract it as the speed is returning.

Mr. Nystrom said that he fully appreciated the value of Mr. Bilgram's paper. The subject of isochronous governors was very fully discussed before the Committee of Science and the arts two years ago. He (Mr. Nystrom) had disagreed with Mr. Bilgram then, and he disagreed with him now, although he was willing to admit that his friend was theoretically correct. If we turn a cylinder in a good lathe we say that it is practically cylindrical, but if we put it to the test we will

find that it is not an absolutely true cylinder. The pendulum of a clock is practically isochronous; it answers the purpose of an isochronous pendulum, yet theoretically it is not isochronous because of the slight variation in the angle of vibration. But isochronous pendulums—the cycloidal—can be made. These are theoretically isochronous, and cycloidal pendulums were tried on clocks in Vienna some years ago, when it was found that they did not keep as good time as common pendulums. Though theoretically more perfect they were not as good in practice. Applying this to the subject of governors, I say that the latter can be made *practically* isochronous. When a governor, running at a constant speed, can keep it almost closed, it is practically an isochronous governor. The water-wheel governor is practically isochronous. It is true that there is a slight variation while the gate is being moved up or down, but it is so slight as to be of no importance. In further illustration of the same point as to the difference between theory and practice, Mr. Nystrom spoke of Prof. Mark's machine for drawing absolutely straight lines, saying that Seller's planer would make lines a great deal nearer straight in practice, although Mark's machine might be theoretically more perfect. In conclusion, he submitted to the good judgment of the Institute that governors can be made *practically* isochronous.

Mr. Bilgram called Mr. Nystrom's attention to a very decided difference between water-wheel and steam engine governors, the former not having the factor of periodicity in the admission of steam to contend against.

Prof. Marks said that he must protest against the use of the word isochronous as applied to governors, since the latter could not become operative until a change of speed had made it necessary for them to act. As to his machine for drawing a straight line, it was only a rough model he had shown, and yet that made a straight line as far as the eye could detect, when comparing it with a line made by snapping a drawn string. Possibly the line was an arc with a radius of 100,000 miles, but it was practically a straight line.

Mr. Nystrom asked the indulgence of the Institute, and said that, though he admitted the correctness theoretically of the position assumed by Messrs. Bilgram and Marks, he nevertheless thought the term isochronous should still be employed to describe governors that are practically perfect. If not, and its use is to be restricted, it might as well

be struck from the dictionary of technical terms, for it can really be of no practical use.

The Secretary's report included accounts of Goldschmid's Aneroid Barometers, with Micrometrical Screws, two forms of which were shown; Juvet's Time Globe, showing the time of any place by a glance on the equatorial zone, all the latest geographical discoveries, isothermal lines, and ocean currents; Beck's Large Stage Microscope, made for Dr. Seiler, and having a vertical and horizontal motion of four inches, for sections of the brain, etc., of that size; Green's Extension Tables; Von Laer's Binder for periodicals, each number of which is held in place by a separate thin metal rod, pivoted at one end and locked in position at the other by means of a horizontal latch; Haworth's Turbine Motors for Sewing Machines; and Powell's Burglar Alarm, by which a paper cartridge is exploded when an attempt is made to open a door or window to which it may be applied. Short papers were read on the Hudson River Tunnel; Luminous Paints; Speed of Locomotive Engines; New Gatling Gun; Stewart's Electric Lamp; Engraving and Carving Machines; Pneumatic Dispatch Tubes; Destructive Western Tornadoes; and the Result of the Examination of Silver Ores from Leadville, Colorado.

Mr. D. S. Holman exhibited a new Compressorium he had devised for observations with high powers under the microscope; also a moist chamber, and an apparatus for showing cell structure.

Mr. Mitchell moved that a Committee of Conference be appointed, to consist of five members of the Institute, to meet a similar committee from the State Agricultural Fair Exhibition, and report to the Board of Managers at their next meeting, which was carried.

The President announced that he would appoint the present Committee on Exhibitions.

Prof. Frazer moved for the appointment of a Committee of Chemists, to examine and report on the relative scientific value and novelty of the methods described by experts in a recent will trial, but the consideration of the resolution was, on motion of Mr. McKean, postponed for a month.

Mr. Cartwright moved that the Franklin Institute tender a vote of thanks to Mr. Bartol for his liberal gift to the Drawing Schools of the Institute, which was carried.

There being no further business, the Institute adjourned.

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